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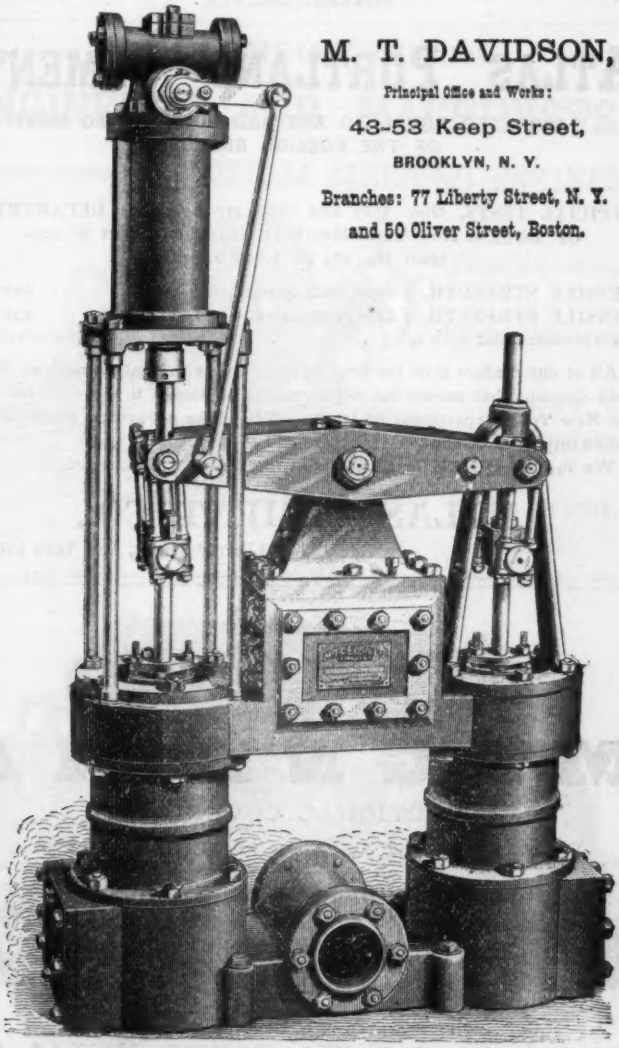

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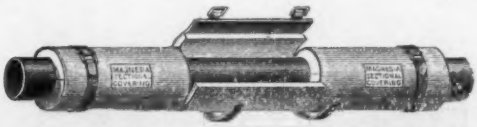

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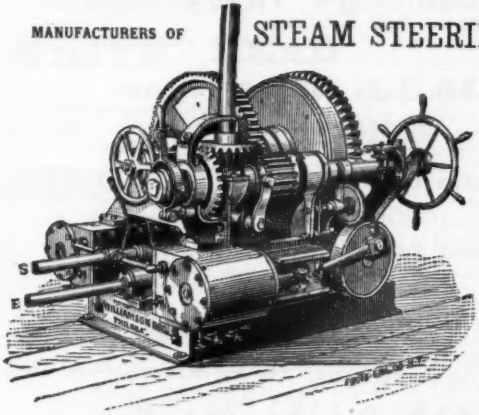

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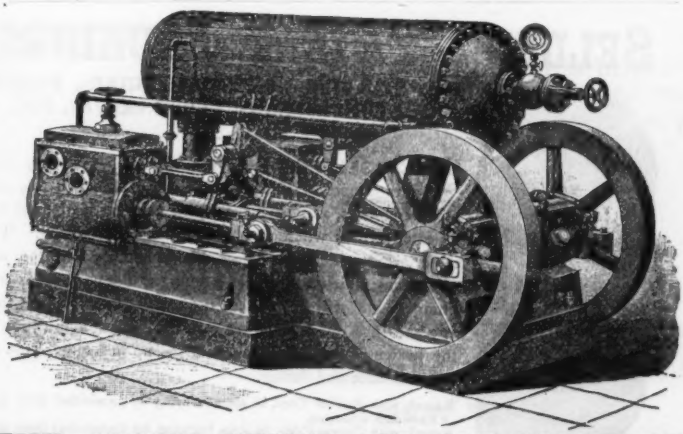

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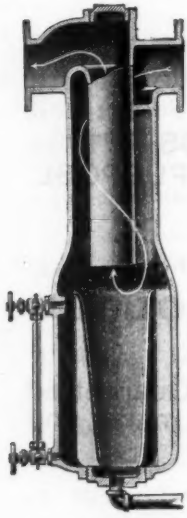

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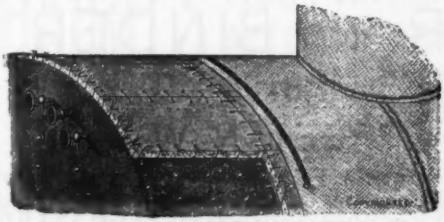

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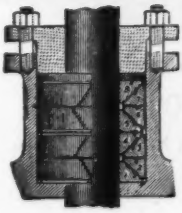

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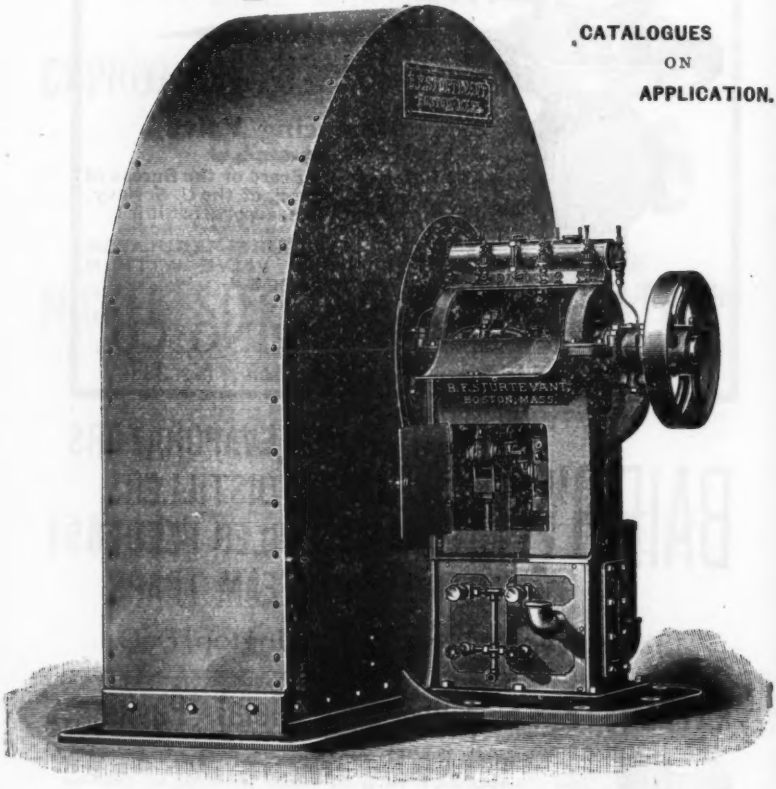

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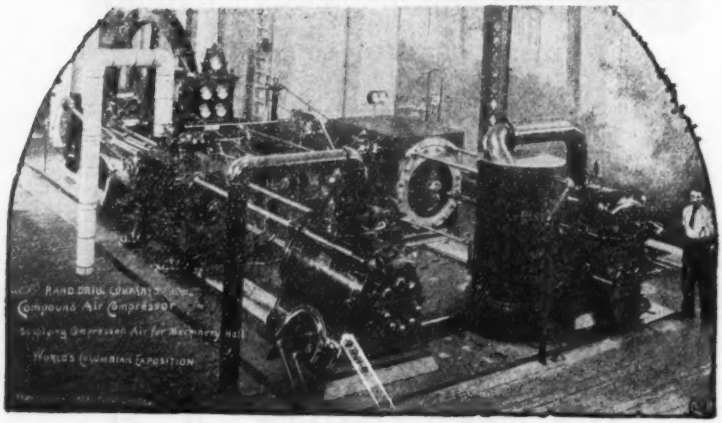

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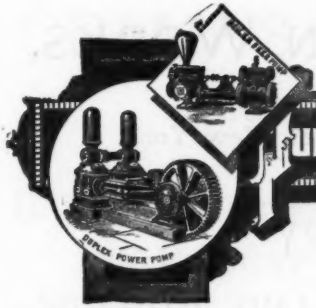

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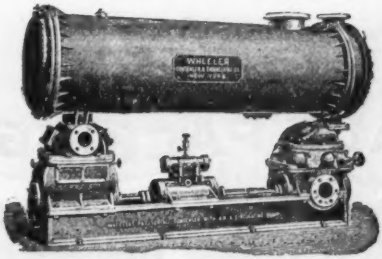

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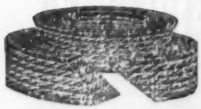

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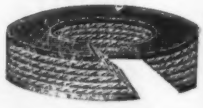

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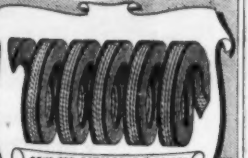

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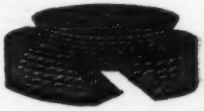

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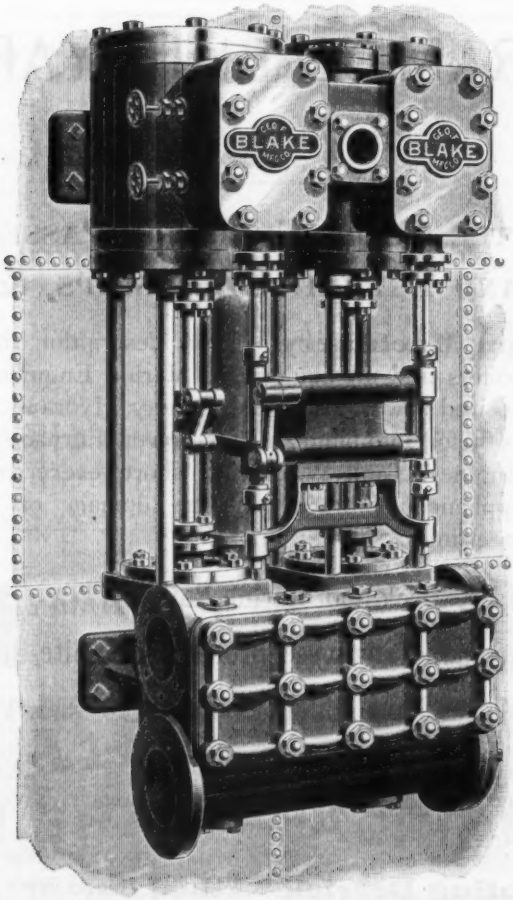

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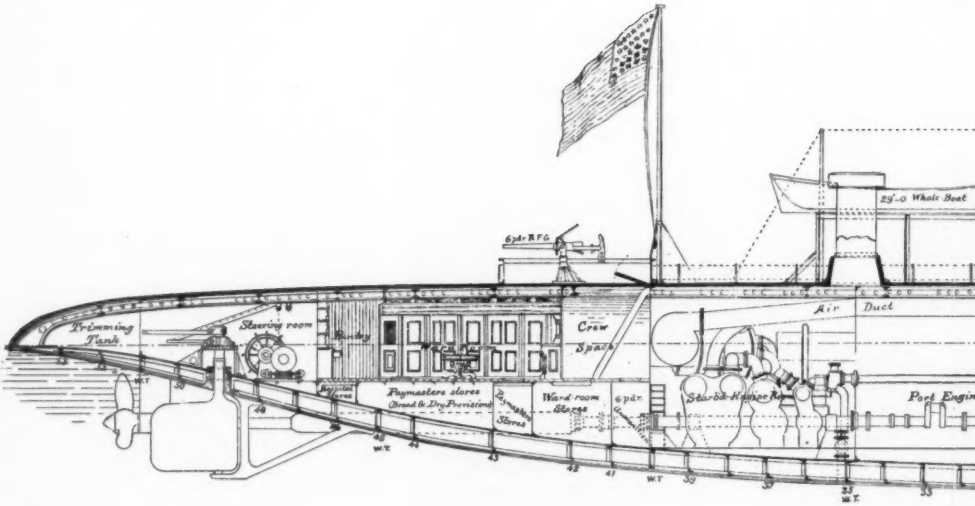

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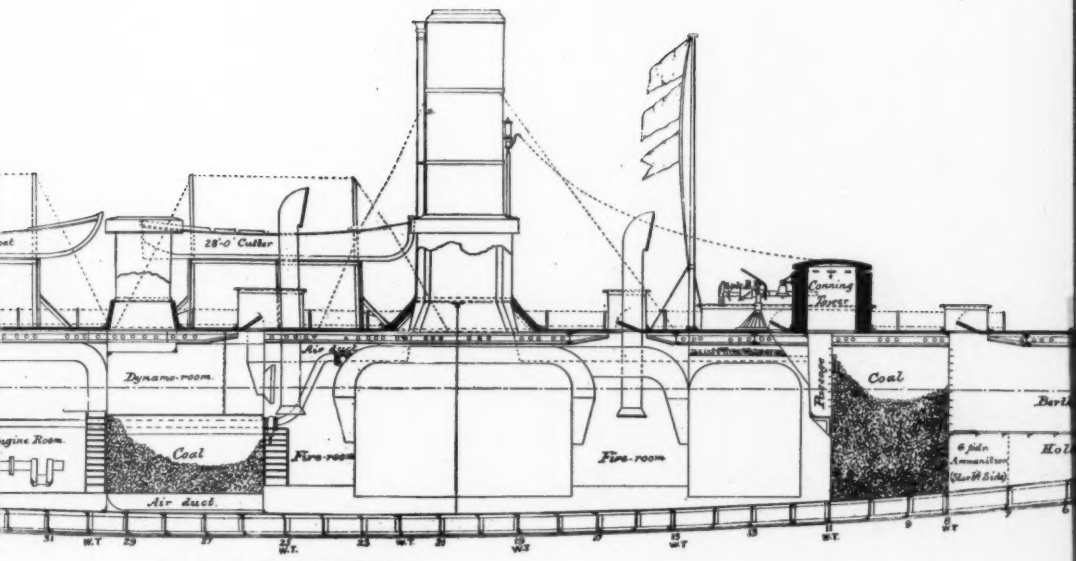

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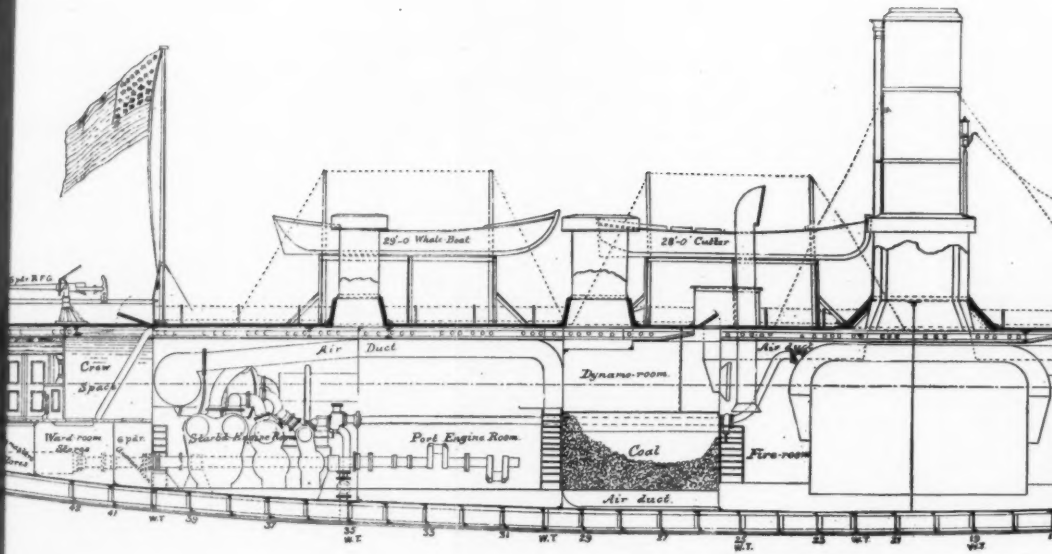

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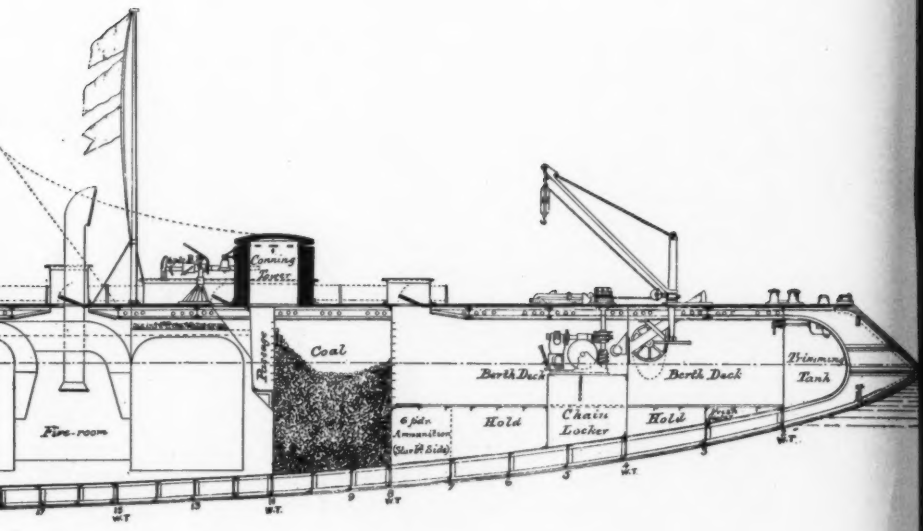
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In accordance with the resolution adopted on January 11, 1896, at the Annual Meeting of the Society of American Naval Engineers, the Council takes pleasure in offering for competition, according to the rules of the resolution, (printed on page 437 of this number of the JOURNAL,) the sums of $75 and $25 respectively, and suitable medals which will be prepared, for the two best, original papers. The Council will award "Honorable Mention" to such other papers as may deserve this distinction.

By the broad terms of the resolution, the subject of a paper may be in the form of an original essay on any matter suitable for this Society, or it may be on the results of original experiment or research. There is no limit to the length of the papers, nor in the number of illustrations which may be thought necessary.

The Council expresses the hope that members and associate members will strive for the honors thus bestowed by the Society, and by their original productions enhance the growing value of the JOURNAL.

By direction of the Council.

Respectfully,

F. C. BIEG,
Secretary-Treasurer.

WASHINGTON, *May 15, 1896.*

JOURNAL

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CONTRACT TRIAL OF THE UNITED STATES COAST LINE BATTLESHIP *MASSACHUSETTS.*

BY PASSED ASSISTANT ENGINEER C. H. HAYES, U. S. NAVY.

By an act approved June 30, 1890, Congress authorized the building of three heavily armored and formidably armed battleships of the first class, primarily intended for coast defence, but to possess sufficient seaworthiness for extended cruises in case of offensive operations. They have been named the *Indiana*, *Massachusetts* and *Oregon*, and the second vessel of this class to be completed, coast line battleship No. 2, the *Massachusetts*, was built by the William Cramp & Sons' Ship and Engine Building Company, of Philadelphia, Pa. The general plans and specifications were furnished by the Navy Department, and the detailed drawings from these general designs were prepared by the contractors and submitted to the bureaus concerned for approval as the work progressed.

The contract for this vessel was signed November 18, 1890, the price for hull and machinery, exclusive of armor and armament, being $3,063,000.

The speed guaranteed was 15 knots per hour, to be maintained successfully for four consecutive hours, during which period the air pressure in the fire rooms was not to exceed one inch of water, the vessel to be weighted to a mean draught of 24 feet. It was stipulated that for every quarter knot of speed maintained above 15 knots the contractors should receive a premium, over and above the contract price of the vessel, of $25,000, and that for every quarter knot the vessel failed to reach the guaranteed speed there should be deducted from the contract price the sum of $25,000.

The first keel plate was laid June 25, 1891, the first frame raised July 20, 1891, and the vessel was launched on June 10, 1893.

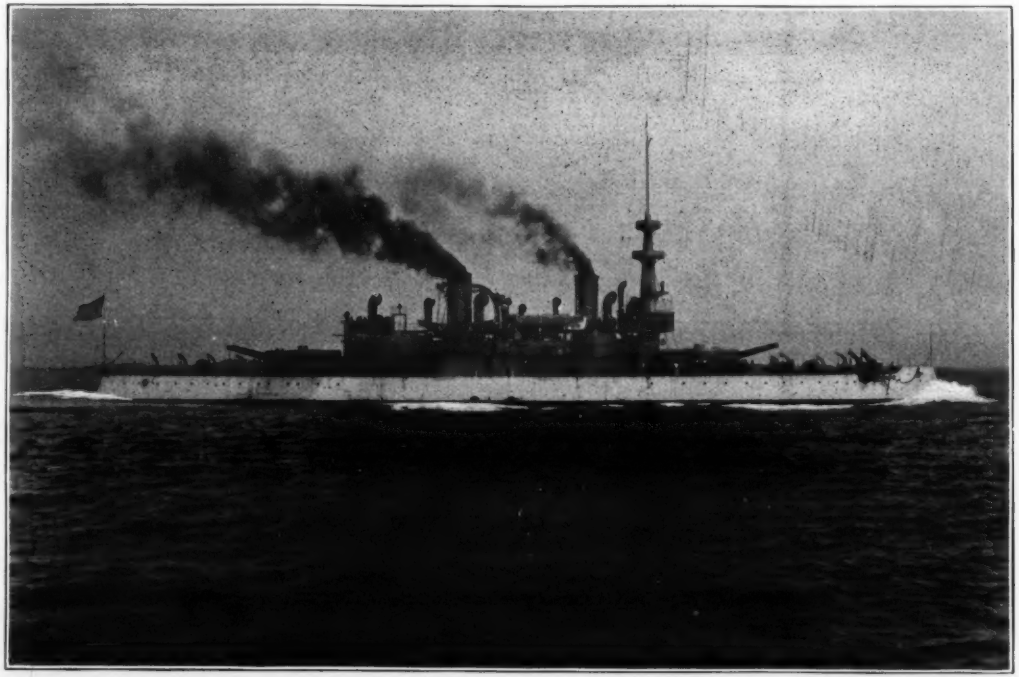
HULL.

The hull is constructed of mild steel, which, together with all other material used in the ship, is of domestic manufacture. The thickness of the outer keel plate is $\frac{3}{4}$ inch, of the inner $\frac{5}{8}$ inch, and of the vertical keel $\frac{1}{2}$ inch. The outer bottom plating is $\frac{5}{8}$ inch thick and the inner plating $\frac{3}{8}$ inch.

There is a double bottom extending from frame 18 to frame 78, a distance of 240 feet, which runs up to the armor shelf. It is 3 feet 3 inches in depth amidships and is divided into 19 water tight compartments. The frames are spaced 4 feet apart within the limits of the double bottom and 3 feet 6 inches apart forward and abaft of these limits. Coffer dams, 6 feet wide, extend forward and abaft the armor belt, on each side of the vessel, from the orlop deck to the berth deck, and are packed with compressed cellulose. The transverse bulkheads are carried through the coffer dams dividing them into compartments, which form part of the 270 water tight subdivisions in the ship.

Hold.—In the hold abaft the engine compartments and forward of the boiler compartments are: Coal bunkers, 6-inch and 8-inch magazines and shell rooms, fixed ammunition rooms, turning gear for 13-inch turrets, store rooms and trimming tanks.

After platform.—On the after platform are: 13-inch magazines and shell rooms, 13-inch handling room, store rooms, steering engine and gear.



FROM A COPYRIGHT PHOTOGRAPH BY W. H. RAU, PHILADELPHIA.

U. S. S. "MASSACHUSETTS."

Forward platform.—On the forward platform are: 13-inch magazines and shell rooms, 13-inch handling room, store rooms.

Orlop deck.—On the orlop deck, forward and abaft the athwartship armor, are: Store rooms and fresh water tanks; and within the citadel, coal bunkers, ventilating fans, dynamo room, hydraulic machinery, 8-inch turret turning machinery, air compressors for torpedo tubes, central station for voice pipes and telephones, auxiliary magazines for 8-inch, 6-inch and rapid fire guns. Outboard on each side is an armored passage extending from bulkhead at frame 29 to bulkhead at frame 64. Inboard of the armored passage, and extending the same length, is an ammunition passage.

Berth deck.—The space on the berth deck is devoted to the living quarters for officers and crew, the auxiliary boilers, coal bunkers, the refrigerating plant and torpedo rooms.

Coal bunkers.—There are 30 coal bunkers with a total capacity of 1,650 tons at 43 cubic feet to the ton. They are distributed as follows: 16 in the hold with a capacity of 1,340 tons; 6 on the orlop deck with a capacity 78 tons; 8 on the berth deck with a capacity of 232 tons. They are filled through chutes and trunks fitted between decks. The trunks are fitted with shunt doors at the top where they pass through the coal bunkers on the berth deck, and vertical doors at the bottom, so that the coal can be passed from these bunkers into the trunks, and through the orlop deck into the bunkers below. Armored shutters are fitted in the trunks where they supply coal to the bunkers through the orlop deck.

There are two ash chutes on each side, on the outside of the vessel, semi-oval in shape. The upper ends, of the chutes extend above the main deck, where hoppers are formed inside. Trolley-ways for carrying the ash buckets are fitted under the deck beams above, leading from the ash hoists to the chutes.

Drainage system.—For draining the compartments there is a 14-inch main drain pipe on the port side and a 7½-inch secondary drain pipe on the starboard side, extending in the double bottom throughout the engine and boiler compartments. Each pipe has branches leading to a cistern in each compartment and is fitted with screw-down non-return valves. The main drain pipe is con-

nected with the port main circulating pump, and through the manifolds with four engine room auxiliary pumps. The secondary drain pipe is connected through the manifolds with the suctions of eight of the auxiliary pumps. The auxiliary feed pumps are connected with the bilge of the boiler compartments, and the fire and bilge pumps with the bilge of the engine compartments and also with the bilge of the compartment next abaft the engine rooms. The side compartments empty directly into the midship compartments by means of water tight sluices on the bulkheads. The compartments at the extremities drain into the compartments at the ends of the main drain pipe by means of gun-metal sluices. Each compartment within the double bottom has its own suction, and these suctions lead to valve boxes placed in the engine rooms. The suctions forward and abaft the limits of the double bottom are led to valve boxes located in the fire rooms and engine rooms respectively. A drain valve is fitted to each compartment above the platform decks, with a strainer box over it, and with a pipe leading to the bilge. For draining above the orlop deck, forward and aft, screw-down valves are fitted in the armor deck, two forward and two aft, with sluice valves in the store room and other bulkheads; from these valves pipes lead the water to the main drain pipe. The waste water from the bath and wash rooms is led by pipes to tanks located in the ammunition passages, and is pumped overboard by a Blake plunger pump, with steam cylinder $4\frac{1}{2}$ inches diameter, plunger $3\frac{3}{4}$ inches diameter, and stroke 7 inches.

The following boats are carried:

1 33-foot steam cutter.
1 30-foot steam cutter.
2 29-foot whale boats.
1 30-foot whale boat gig.
1 32-foot sailing launch.
2 28-foot cutters.
1 26-foot cutter.
1 24-foot cutter.
2 20-foot dinghies.
1 Balsa.
2 Punts.

Length between perpendiculars, feet	348
on L.W.L., feet	348
over all (including rudder), feet and inches	350–10½
Beam, extreme, feet and inches	69– 3
at L.W.L., feet and inches	69– 3
Ratio of length to beam	5.03
Depth in hold from top of main deck beams to top of floor, feet	32
Height of superstructure above main deck beams, feet and inches	7– 4
Draught forward, seagoing trim, feet	23.69
aft, seagoing trim, feet	24.06
mean, seagoing trim, feet	23.88
Displacement, seagoing trim (load draught), tons	10,225.
per inch, at L.W.L., tons	42.76
Area of immersed midship section, square feet	1,540.
L.W.L. plane, square feet	17,980.
Center of gravity of L.W.L. plane, aft of midship section (frame No. 45), ft.	.94
buoyancy above bottom of keel, feet	13.52
aft of midship section, feet	1.86
gravity above bottom of keel, feet	24.
Transverse metacenter above center of buoyancy, feet	15.27
Longitudinal metacenter above center of buoyancy, feet	335.5
Transverse G. M., metacentric height, feet and inches	3–4
Longitudinal G. M., feet	350.
Coefficient of fineness on extreme dimensions	.622
of midship section	.931
of L.W.L.	.746
Cylindrical coefficient	.668
Number of frames	91.
water tight compartments	270.

ARMOR.

The armor protection consists of a side or water line belt of harveyized nickel steel, extending for a distance of about 150 feet abreast of the machinery and boiler spaces, and to the bases of the 13-inch gun turrets. This belt is 3 feet above and 4 feet 6 inches below the normal load water line amidships, diminishing to 4 feet 2½ inches below the load water-line at the ends. The outside surface conforms to the shape of the vessel, with a thickness of 18 inches at the top of the belt, and extending downward 4 feet, from which point it is beveled to a minimum thickness of 8 inches at the top of the armor shelf.

At each end of the water line belt is an athwartship diagonal belt of nickel steel 14 inches thick, carried forward and aft to a

segment of a circle amidships coincident with that of the main barbettes, thus completing the armored citadel.

The citadel is covered with an armored deck of nickel steel, 2¾ inches thick, and forward and abaft the citadel there are protective decks of 3-inch nickel steel. Above the 18-inch side belt, extending to the main deck, there is a casemate of 5-inch nickel steel armor, made up of two ½-inch plates and one 4-inch plate.

The armor of the turrets for the 13-inch guns is of harveyized nickel steel 15 inches thick, and the barbettes protecting the bases of these turrets are of the same material, 17 inches in thickness.

For the turrets of the 8-inch guns, harveyized nickel steel armor 6 inches thick is used, the bases of these turrets being protected by barbettes with armor of the same material, 8 inches thick on the outboard sides and 6 inches thick on the inboard sides. The top plating of all turrets is 2 inches thick, and of the sighting towers, 5 inches and 3 inches thick.

The armored protection of the 6-inch guns is of nickel steel 5 inches thick, made up of two inner thicknesses of ½ inch each and an outer thickness of 4 inches. For the 6-pounder guns on the main deck it is 2 inches thick, and for the 1-pounder guns at the ends of the vessel, the protection consists in having the plating increased to a total thickness of 2 inches in wake of the ports, so that it will act as a shield.

The conning tower is located above the superstructure deck; it is of nickel steel, forged hollow in one piece, 10 inches thick, and has an internal diameter of 6 feet 11 inches.

An armored tube, 7 inches thick and 12 inches internal diameter, extends from the conning tower to the armored deck and protects the electric wires, voice tubes, connection to engine room telegraphs, steering gear and engine tell tales. There is also a tube of 3-inch nickel steel, 54 inches inside diameter, which protects the turning tubes of each 8-inch gun turret and the ammunition passage to the 8-inch guns.

ARMAMENT.

The main battery consists of four 13-inch breech loading rifles, 35 calibers, mounted in pairs in the two main turrets; eight 8-

inch breech loading rifles, 35 calibers, mounted in pairs in the four turrets on the superstructure; and four 6-inch breech loading rifles, two on each side, on the main deck within the superstructure.

The secondary battery consists of twenty 6-pounder Hotchkiss rapid fire guns; six 1-pounder Hotchkiss rapid fire guns; and four light machine guns in the military tops.

The 13-inch turrets are worked by steam, and the guns by hydraulic power; the 8-inch turrets by steam power, and the guns by hand. The 6-inch guns are worked by hand on central pivot carriages.

There are six tubes for Whitehead torpedoes, two on each side, one in the bow, and one in the stern, all discharging directly from the berth deck. Of these tubes, the port after broadside one has been temporarily removed to give additional space for one stateroom for junior officers, but it is held in readiness for reinstallation whenever needed.

The weight of projectile thrown from the main and secondary battery in broadside at one discharge is 5,664 pounds; and from the main and secondary battery at one complete discharge is 6,926 pounds.

MAIN ENGINES.

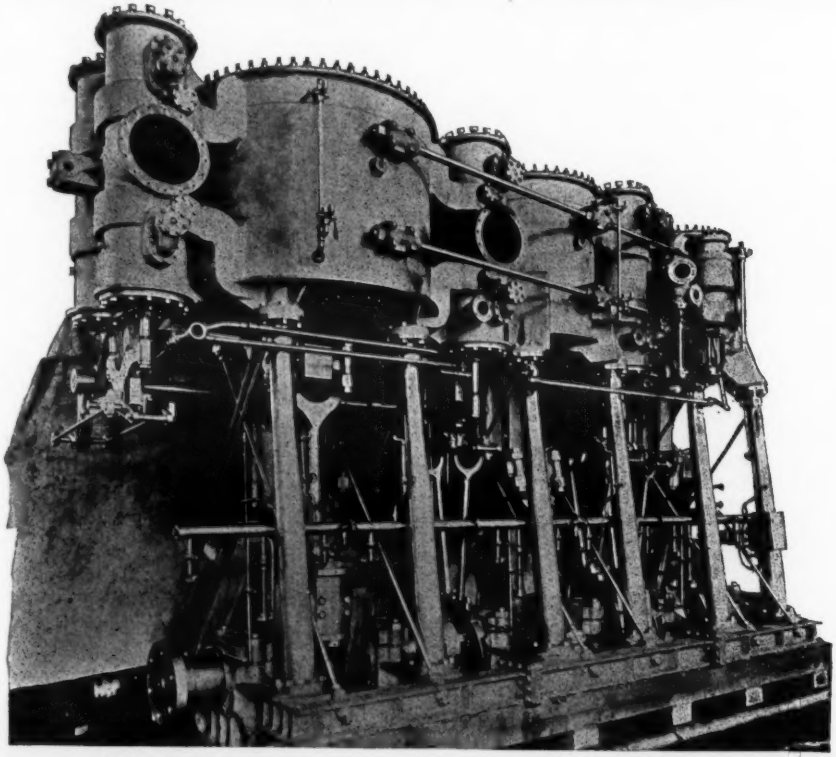
There are two vertical inverted, direct acting, triple expansion engines placed abreast of each other in separate water tight compartments, the high pressure cylinders being forward.

Each cylinder is supported by an inverted cast-steel Y frame on one side, and by two hollow forged-steel cylindrical columns on the other. The intermediate and low pressure cylinders are steam jacketed on the sides and bottom, but the high pressure are not, but are fitted with working liners. There are no starting valves on the cylinders, provision being made for starting the engines by admitting live steam to the receivers. The relief valves for the cylinders are placed on the valve chest casings, on connections between the steam and exhaust sides of the main valves. There are two receivers for each engine, consisting of exhaust pipes and valve chests, the safety valves of which are set at 100 pounds for the I.P. and 60 pounds for the L.P. The

main valves are of the single ported piston type, there being for each engine, one for the H.P., two for the I.P. and four for the L.P. cylinder. They are provided with balance pistons, the cylinders of which form part of the upper covers of the valve chests. The valve gear is of the Stephenson type with double bar links. There are no independent cut-off valves, but provision is made to cut off in each cylinder, varying from .5 to .7 of the stroke, by means of a block to which the suspension links are attached, which block can be moved by hand screw gear in a slot in the end of the arm on the reversing shaft.

The main pistons are steel castings, dished, and are each fitted with two packing rings $\frac{5}{8}$ inch wide and $\frac{3}{4}$ inch thick. The piston rods and connecting rods are of forged steel. The crossheads are of forged steel, and each has a manganese bronze slipper, the sliding faces of which are fitted with white metal. The crosshead guide to take the thrust when going ahead is of cast iron bolted to the inverted Y frame. The back of the guide is recessed and covered with wrought-iron plates to form a passage for circulation of water. Cast-iron lips are bolted on each side of the go-ahead guide to take the thrust when backing. The eccentrics are of cast iron. Each backing eccentric is securely keyed on the shaft, and each go-ahead eccentric is secured to the corresponding backing one by through bolts in slotted holes. The eccentric straps are of composition, faced with white metal, and the eccentric rods of forged steel. The I. P. and L.P. valve stems have manganese bronze crossheads which take hold of the link blocks directly. Each engine bed plate consists of three sections of steel castings. The steam reversing gear consists of a cylinder 14 inches in diameter and 20 inches stroke, secured to an engine Y frame, the piston rod being connected to an arm on the reversing shaft. The valve is moved by a hand lever and is controlled by a floating lever. The hand reversing gear consists of a wheel, worm shaft, pinion and rack, the latter being connected to an arm on the reversing shaft.

There is a double cylinder, simple, inverted, turning engine with cylinders 7 inches in diameter and 7 inches stroke secured to the high pressure Y frame. It drives a worm wheel on the



TRIPLE-EXPANSION ENGINE U. S. S. "MASSACHUSETTS."

forward end of the high pressure crank shaft by means of worm gearing and a second worm; the latter is made to slide on a feather key, and is held in place by a collar below and a removable key above it. A ratchet is fitted to the shaft of the engine for turning by hand.

Each main engine is fitted with a disc stop valve 13¼ inches in diameter, having a screw stem and a balance piston, and a butterfly throttle 15⅛ inches in diameter. The main steam pipes are of copper and strengthened with steel bands 6 inches apart.

In the port engine room there is a distributing oil tank supplied from the main oil tanks by a Blake duplex pump, steam cylinders 2 inches in diameter, oil cylinders 1¼ inches in diameter, stroke 2¾ inches. The tank is fitted with an overflow pipe. Distributing pipes lead to the various manifolds which are fitted with adjusting valves, and from the manifolds, tubes lead to the various parts to be lubricated. The suction pipe of the pump is fitted with a strainer.

Cylinders, number for each engine	3
diameter of H.P., inches	34½
diameter of I.P., inches	48
diameter of L.P., inches	75
Stroke of pistons, inches	42
Valves, diameter of H.P. (one for each cylinder) inches	17
diameter of I.P. (two for each cylinder), inches	17
diameter of L.P. (four for each cylinder), inches	17
Balance pistons, diameter of H.P., inches	5½
diameter of I.P., inches	5½
diameter of L.P., inches	7
Valve stems, H.P. (1) diameter, inches	2⅝
H.P. (1) diameter through valve, inches	1¾
I.P. (2) diameter, inches	2⅝
I.P. (2) diameter through valve, inches	1¾
L.P. (4) diameter, inches	2⅝
L.P. (4) diameter through valve, inches	1¾
Main steam pipe (13 inches diameter) area of cross section, square inches	132.73
Exhaust pipe to I.P. cylinder (16½ inches diameter) area of cross section, square inches	213.82
to L.P. cylinder (20½ inches diameter) area of cross section, square inches	330.06
to condenser (2) (18½ inches diameter) area of combined cross sections, square inches	537.6

Volume swept by H.P. piston per stroke, cubic feet			22.02
I.P. piston, per stroke			43.51
L.P. piston, per stroke, cubic feet			106.91
Ratio of net area of H.P. to I.P. pistons			1 95
I.P. to L.P. pistons			2.46
H.P. to L P. pistons			4.84
Clearance of H.P. cylinder per cent...	Starboard...	Top	15.20
		Bottom	23 20
	Port	Top	14.30
		Bottom	24.40
Clearance of I.P. cylinder, per cent...	Starboard...	Top	12.10
		Bottom	22.80
	Port	Top	12.10
		Bottom	21.90
Clearance of L.P. cylinder, per cent....	Starboard...	Top	9.90
		Bottom	19.40
	Port	Top	8.90
		Bottom	21.00
Piston rods, diameter, inches			7
length from piston to crosshead, feet and inches			5-5⅝
Connecting rods, length from center to center, feet			7
diameter of upper end, inches			6⅝
diameter of lower end, inches			8½
thickness (sides as faced), inches			6⅝
crosshead bolts (4), diameter, inches			3
crank pin bolts (2), diameter, inches			4¼
Crossheads, surface (ahead), square inches			446½
surface (backing), square inches			352½
Outside crosshead pins (2) diameter, inches			7½
Crosshead pins, length, inches			9⅛
Reversing gear, steam cylinder, diameter, inches			14
stroke, inches			20

Shafting and Bearings.—The crank, line and propeller shafting is hollow and of forged steel. The crank shaft of each engine is in three interchangeable sections, the cranks placed at angles of 120 degrees, and for the ahead motion follow in the order H.P., I.P. and L.P. There are two sections of line shafting to each engine supported on three bearings. The propeller shafts are fitted with a composition casing from inboard the stern tube stuffing box to the propellers; they extend far enough inboard to allow the inboard stern bearings to be withdrawn without moving the shafts. The shaft coupling bolts are tapered and finished to fit the holes snugly. They are put in from the after side of the

coupling and are set up on the forward side with a wrought-iron nut and split pin.

Each thrust bearing is of cast iron of the horse shoe pattern. The end and side walls of the pedestal form an oil trough outside of which, both forward and aft the horse shoes, is a composition bearing lined with white metal for taking the weight of the shaft. The cap of this bearing is of cast iron lined with white metal. The horse shoes, eleven in number, are 21 inches in diameter, of a mixture of cast iron and steel lined with white metal, and adjusted by brass nuts on steel side rods 3 inches in diameter. There is an oil cup in the top of each horse shoe, from which there is an oil hole to each collar, the white metal being channeled for the distribution of the oil. At each end of the bearing there is a divided stuffing box and gland to prevent the escape of oil. The pedestal is bolted to a cast-iron sole plate fitted with wrought-iron wedges at each end of the pedestal for adjusting the bearing fore and aft.

Crank shafts, diameter inches	14
axial hole, inches	6
coupling discs, diameter, inches	26½
coupling discs, thickness, inches	3¼
tapered coupling bolts in one flange (6), diameter, inches	3⅛ to 3 1/16
journals, diameter, inches	14
journals, length, inches	17⅜
length of each section, feet and inches	8–6
Crank pins, diameter, inches	15
length, inches	17
axial hole, inches	6½
Crank webs, width, inches	15½
thickness, inches	9¼
Thrust shafts, diameter, inches	13¾
diameter of coupling disc, inches	26½
axial hole, inches	6
collars, number each shaft	11
collars, diameter, inches	21
collars, thickness, inches	2
collars, distance between, inches	4
surface, total for both engines, square inches	4,353.18
length, feet and inches	16–7/8
Line shafts, diameter, inches	13¾
axial hole, inches	6

Line shafts, diameter of coupling discs, inches	26½
(2) total length, feet	40
Propeller shafts, diameter, inches	14
axial hole, inches	6
diameter of coupling discs, inches	26½
length, feet and inches	40–8
Stern bracket bearing, length, inches	49½
diameter, inches	15¾
Stern tube bearing, length { forward, inches	33
{ aft, inches	35½

There are six coupling bolts for each section of shafting. They are taper, from $3\frac{1}{8}$ to $3\frac{1}{16}$ inches in diameter.

Main Condensers.—There are two main condensers, one for each engine, of cast composition, in five sections, including the heads, and bolted together. The circulating water passes through the tubes. Baffle plates are fitted to direct the steam over the tubes, and plates are provided for supporting the tubes and also to act as baffle plates.

Diameter of shell (inside) feet and inches	5–9
Thickness of shell, inch	½
Length over water heads, feet	12
Tubes, diameter (outside). inch	⅝
length between heads, feet and inches	10 –3
thickness, No. 20 B.W.G., inch	.035
number in each condenser	3,790
Cooling surface, each condenser, square feet	6,355
total, square feet	12,710
Ratio of total cooling to total heating surface { Main boilers	1 to 1.356
{ Main and auxiliary boilers,	1 to 1.51

Auxiliary Condensers.—There is in each engine room a Wheeler condenser connected with the auxiliary exhaust pipes. Each has a horizontal combined air and circulating pump of Blake type, the steam cylinder being between the water cylinders, and all the pistons being on one rod. The tubes are arranged and packed as in the main condensers.

Cooling surface, one condenser, square feet	400
Diameter of steam cylinder, inches	8
water cylinder (circulating), inches	9
air pump cylinder, inches	9
Stroke, common, inches	10

Main Air Pumps.—For each main engine there is a Blake double, vertical, single acting air pump, similar to those on the *Minneapolis.* The steam cylinders are placed directly over the pump cylinders, the pump rods and piston rods forming a continuous length. The pumps are connected by means of a beam, which is pivoted at its center, and from which beam the valve motion is actuated. The beam receives its motion through links swinging from crossheads on the pump and piston rods.

Diameter of steam cylinders (2), inches	12
pump cylinders (2), inches	25
Stroke, inches	18
Diameter of piston rods, inches	2¼
pump rods, inches	4
Kind and diameter of pump valves (vulcanized rubber), inches	5½
Ratio of volume swept by L.P. piston, per stroke, to that of the two air pump buckets, per stroke	10.59

Main Circulating Pumps.—For each main condenser there is a centrifugal double inlet circulating pump, which is arranged to draw from the sea, bilge and main drain pipe, and to discharge either into the condenser or directly overboard. It is driven by a horizontal single cylinder engine. Each pump is capable of discharging 9,000 gallons of water per minute from the bilge. The sea and bilge injection valves are fitted with a self-locking arrangement so that both cannot be opened at the same time.

Diameter of steam cylinder, inches	12
Stroke, inches	6
Diameter of pump runner, inches	32
Width of runner, inches	at hub 6¾, at rim 2¾
Diameter of inlet nozzle, inches	15
outlet nozzle, inches	15

Screw Propellers.—The propellers are of manganese bronze, each with three adjustable blades bent back 15½ degrees. They are true screws, with the pitch variable from 14 feet 3 inches to 16 feet 3 inches. Each boss is secured to the shaft by a feather key and a wrought-steel nut screwed on and locked in place. The end of the hub is covered with a composition cap.

Number of blades	3
Diameter, feet and inches	15–6
of hub, feet and inches	3–11½
Length of hub, feet and inches	3–1
Pitch as set, feet	16
Greatest width of blade (4 feet from axis), inches	45 1⅜
Helicoidal area of each screw, square feet	53.859
Projected area, square feet	45.24
Disc area, square feet	188.69
Pitch ÷ diameter	1.03
Helicoidal area ÷ disc area	.285
Projected area ÷ disc area	.24
Disc area of both screws ÷ I.M.S.	.245
Immersion of center at mean draught (23.88 feet), feet	15.88
Center above lowest point of keel, feet	8
from center line of vessel, feet and inches	11–10

BOILERS.

There are four double-ended main and two single-ended auxiliary steel boilers of the horizontal fire tube type. Each main boiler has eight, and each auxiliary boiler two corrugated furnaces. The shell of each main boiler is made up of three courses of three plates each. The longitudinal joints of the shells of the main boilers are treble riveted with double butt straps, and the circumferential joints are lapped and treble riveted. The shell of each auxiliary boiler is in one course of two plates, double butt strapped and treble riveted, the joints with the heads lapped and double riveted. The joints in furnaces and combustion chambers are single riveted. The heads of the main boilers are flat; those of the auxiliaries are curved at the top to a radius of 2 feet 2½ inches for the front head, and 2 feet 1 39/64 inches for the back head. The furnaces are fitted with "Cone's" patent shaking grate bars. Each main boiler has one quadruple 3½-inch safety valve in one case, and each auxiliary boiler one 3-inch double safety valve in one case. Weir's hydrokineters are fitted to each main boiler for circulating the water while raising steam if there is steam in one boiler. The auxiliary feed pumps can be used to circulate the water, pumping from the bottom blow and delivering through the auxiliary feed checks, the main and auxiliary internal feed pipes being connected and arranged to give a good distribution of the water. The tubes in all boilers are of steel.

The main boilers are located fore and aft in four water tight compartments. There is a passageway amidships extending from the athwartship engine room bulkhead to the athwartship bulkhead of the forward fire rooms, and in this passageway there are water tight doors to each fire room. By this arrangement there are two athwartship fire rooms in each main boiler compartment, and eight main fire rooms in all. The auxiliary boilers are located on the berth deck in separate boiler rooms. There are two main and two auxiliary smoke pipes, the latter running up inside the former.

MAIN BOILERS.

Steam pressure, pounds	160
Number of boilers	4
Length, outside to outside of tube beads, feet	18
Diameter, outside, feet	15
Thickness of shell, inches	$1\frac{9}{64}$
heads, top, inch	1
bottom, inch	$\frac{3}{4}$
tube sheets, inch	$\frac{5}{8}$
furnaces, inch	$\frac{1}{2}$
Combustion chambers, number in each boiler	4
thickness of plates, inch	$\frac{9}{16}$
width at top, inside, feet and inches	$2-5\frac{5}{8}$
depth, feet and inches	$7-2\frac{5}{8}$
Furnaces, greatest external diameter, feet and inches	3–4
least internal diameter, feet	3
length of grate, feet and inches	5–9
number in each boiler (corrugated)	8
Tubes, outside diameter, inches	$2\frac{1}{2}$
length between tube sheets, feet and inches	$6-1\frac{1}{4}$
number of ordinary	676
number of stay	248
spaced vertically, inches	$3\frac{1}{2}$
horizontally, inches	$3\frac{3}{4}$
thickness of ordinary, B.W G. No. 12, inch	.109
stay, B.W.G. No. 6, inch	.203
Diameter of rivets in shell sheets, inches	$1\frac{1}{4}$
screw stays, inches	$1\frac{7}{8}$
Number and diameter of through upper braces, inches	24 of $2\frac{1}{4}$, 3 of $2\frac{1}{2}$
lower braces, inches	3 of $1\frac{3}{4}$
braces around lower manholes, inches	12 of $1\frac{3}{4}$
from head to back tube sheets, inches	20 of 2
Heating surface, tube, square feet	3,647.5

Heating surface, furnace, square feet	245
combustion chambers, square feet	418
total, square feet	4,310.5
Grate surface, square feet	138
Area through tubes, square feet	25.13
over bridge walls, square feet	15 56
Volume of furnaces and combustion chambers above grates, cubic feet	559.93
Steam room, water six inches above tubes, cubic feet	737.41
Water surface, water six inches above tubes, square feet	239.22
Smoke pipes (2), diameter, feet	7
area of both, square feet	68.42
height above lowest grates, feet	70
Number and diameter of safety valves (four on one base), inches	4 of $3\frac{1}{2}$
Diameter of boiler main stop valves, inches	9
auxiliary stop valves, inches	5
Totals for four boilers:	
Heating surface, tube, square feet	14.590
furnaces, square feet	980
combustion chambers, square feet	1,672
total, square feet	17,242
Grate surface, square feet	552
Area through tubes, square feet	100.52
over bridge wall, square feet	62.24
Volume of furnaces and combustion chambers above grates, cubic feet,	2,239.72
steam room, cubic feet	2,949.64
Area of water surface, square feet	956 88
Ratios:	
Tube H.S. to G.S.	26.43 to 1
Furnace H.S. to G.S.	1.78 to 1
Combustion chamber H.S. to G.S.	3.01 to 1
Total H.S. to G.S.	31.24 to 1
Area through tubes to G.S.	.18 to 1
Steam room per square foot of G.S.	5 34 to 1
Volume of furnaces and combustion chambers above grates to G.S.	4 06 to 1

AUXILIARY BOILERS.

Steam pressure, pounds	160
Number of boilers	2
Length, outside to outside of tube beads, feet and inches	8-6
Diameter, outside, feet and inches	10–$1\frac{28}{32}$
Thickness of shell, inch	$\frac{27}{64}$
Thickness of heads, top, inch	$\frac{27}{64}$
bottom, inch	$\frac{3}{4}$
Thickness of tube sheets, inch	$\frac{3}{4}$
Thickness of furnaces, inch	$\frac{15}{32}$
Combustion chambers, number in each boiler	2

Combustion chambers, thickness of plates, inch	$\frac{1}{2}$
width at top, inside, inches	$23\frac{1}{4}$
depth, feet and inches	3–$8\frac{3}{4}$
Furnaces, greatest external diameter, feet and inches	3–1
least internal diameter, feet and inches	2–9
length of grate, feet	6
number in each boiler, corrugated	2
Tubes, outside diameter, inches	$2\frac{1}{2}$
length between tube sheets, feet and inches	5–$10\frac{1}{2}$
number of ordinary	158
number of stay	58
spaced vertically, inches	$3\frac{1}{2}$
spaced horizontally, inches	$3\frac{3}{4}$
thickness of ordinary, B.W.G. No. 12, inch	.109
thickness of stay, B.W.G. No. 6, inch	.203
Diameter of rivets in shell sheets, inch	1
Diameter of screw stays, inches	$1\frac{9}{8}$
Pitch of screw stays, inches	$6\frac{1}{2}$
Number and diameter of through upper braces, inches	8 of 2
lower braces, inches	2 of $1\frac{9}{16}$, 1 of $1\frac{3}{4}$
braces from head to back tube sheets, inches	2 of 2, 2 of $1\frac{9}{16}$
Heating surface, tube, square feet	824.67
furnaces, square feet	55.4
combustion chambers, square feet	96.25
total, square feet	976.32
Grate surface, square feet	32
Area through tubes, square feet	5.43
over bridge walls, square feet	2.62
Volume of furnaces and combustion chambers above grates, cubic feet	104.58
Steam room, water six inches above tubes, cubic feet	114
Water surface, water six inches above tubes, square feet	72.94
Smoke pipes (2), diameter, feet and inches	2–$3\frac{3}{4}$
area of both, square feet	8.4
height above lowest grates, feet and inches	46–7
Number and diameter of safety valves (2 on one base), inches	2 of 3
Diameter of boiler stop valves, inches	5
Totals for two boilers:	
Heating surface, tube, square feet	1,649.34
furnaces, square feet	110.8
combustion chambers, square feet	192.5
total, square feet	1,952.64
Grate surface, square feet	64
Area through tubes, square feet	10.86
over bridge walls, square feet	5.24
Volume of furnaces and combustion chambers above grates, cubic feet,	209.16
steam room, cubic feet	228
Area of water surface, square feet	145.88

Ratios:	
Tube H.S. to G.S.	25.77 to 1
Furnace H.S. to G.S.	1.73 to 1
Combustion chamber H.S. to G.S.	3 to 1
Total H.S. to G.S.	30.51 to 1
Area through tubes to G.S.	.169 to 1
Steam room per square foot of G.S.	3.56 to 1
Volume of furnaces and combustion chambers above grates to G.S.	3 27 to 1
Totals for all boilers:	
Heating surface, tube, square feet	16,239.34
furnaces, square feet	1,090 8
combustion chambers, square feet	1,864.5
total, square feet	19,194.64
Grate surface, square feet	616
Area through tubes, square feet	111.38
over bridge walls, square feet	67.48
Volume of furnaces and combustion chambers above grates, cubic feet,	2,448.88
steam room, cubic feet	3,177.64
Area of water surface, square feet	1,102.76
Ratios of all boilers:	
Tube H.S. to G.S.	26.36 to 1
Furnace H.S. to G.S.	1.77 to 1
Combustion chamber H.S. to G.S.	3.03 to 1
Total H.S. to G.S.	31.16 to 1
Area through tubes to G.S.	.181 to 1
Steam room per square foot of G.S.	5.16 to 1
Volume of furnaces and combustion chambers above grates to G.S.	3.97 to 1

Forced Draft.—The closed fire room system of forced draft is used. The air is supplied by ten Sturtevant blowers, one in each main and in each auxiliary fire room. The fans are driven by two cylinder, vertical, simple, enclosed engines with cranks at 180 degrees.

BLOWERS IN MAIN FIRE ROOMS.

Diameter of steam cylinders, inches	5
Stroke, inches	4
Diameter of piston rod, inches	1⅛
Diameter of fan, inches	60
Width of fan at rim, inches	14
Area of induction nozzle, square inches	1,060.7
eduction nozzle, square inches	2,241

BLOWERS IN AUXILIARY FIRE ROOMS.

Diameter of steam cylinders, inches	3.5
Stroke, inches	2.5

Diameter of piston rod, inch	$\frac{3}{4}$
Diameter of fan, inches	36
Width of fan at rim, inches	12
Area of induction nozzle, square inches	520.7
eduction nozzle, square inches	1,056

Ventilating Fans.—There is in each engine room a Sturtevant ventilating fan, which is used only for engine room service. For ventilating the ship generally, there are four fans situated on the orlop deck, and they are so arranged, by means of reversible valves, as to exhaust from, or force air to the various parts of the ship. The fans are driven by engines similar to those of the forced draft blowers.

Diameter of steam cylinders (2), inches	4
Stroke, inches	3
Diameter of piston rods, inch	$\frac{7}{8}$
Diameter of fan, inches	48
Width of fan, inches	19

Feed Pumps.—In each feeding fire room of the main boilers, and in each fire room of the auxiliary boilers, there are two vertical, duplex, double acting Blake pumps, one for the main and one for the auxiliary feed. The main and auxiliary feed systems are not connected, but any pump can be used to feed any boiler. The main feed pumps draw from the feed tanks and deliver only to the boilers. The auxiliary feed pumps draw from the feed tanks, sea, bilge, secondary drain pipe and boilers, and deliver into the boilers, fire main and overboard. The dimensions of the pumps in the main fire rooms are: Steam cylinders, 8 inches diameter; water cylinders, 5 inches diameter; stroke, 12 inches. The capacity of each pump is 200 gallons per minute. Those in the auxiliary fire rooms are: Steam cylinders, 6 inches diameter; water cylinders, $4\frac{1}{8}$ inches diameter; stroke, 7 inches. The capacity of each pump is 100 gallons per minute.

Feed, Fire and Bilge Pumps.—In each engine room there is a vertical, duplex, double acting Blake pump which draws from the sea, the bilge, the secondary drain pipe, the drainage cistern, the feed tanks and the air pump suctions, and delivers into the main and auxiliary feed pipes, the fire main and overboard.

Their dimensions are: Steam cylinders, 12 inches diameter; water cylinders, 7 inches diameter; stroke, 12 inches. The capacity of each pump is 400 gallons per minute.

Fire and Bilge Pumps.—In each engine room there is a vertical, duplex, double acting Blake pump which draws from the sea, the bilge, the secondary drain pipe and the drainage cistern, and delivers into the fire main and overboard. Their dimensions are: Steam cylinders, 12 inches diameter; water cylinders, 7 inches diameter; stroke, 12 inches. The capacity of each pump is 400 gallons per minute.

Water Service Pumps.—In each engine room there is a vertical, duplex, double acting Blake pump which draws from the sea, and delivers into the water service pipes and fire main. Their dimensions are: Steam cylinders, 8 inches diameter, water cylinders, 5 inches diameter; stroke, 12 inches. The capacity of each pump is 200 gallons per minute.

LIST OF STEAM PUMPS.

Purpose.	Type.	Location—room.	Suction from—	Gals. per minute each pump.
2 main air pumps	Vertical twin	Engine	Condensers	.....
2 main circulating	Centrifugal	Engine	Sea or bilge	9,000
4 main feed	Vertical duplex	Main boiler	Feed tanks	200
4 auxiliary feed	Vertical duplex	Main boiler	Sea, tanks, bilge, or boilers.	200
2 auxiliary boiler main feed	Vertical duplex	Aux'y boiler	Feed tanks	100
2 auxiliary boiler aux. feed	Vertical duplex	Aux'y boiler	Sea or tanks	100
2 feed, fire and bilge	Vertical duplex	Engine	Sea, tanks or bilge	400
2 fire and bilge	Vertical duplex	Engine	Sea or bilge	400
2 water service	Vertical duplex	Engine	Sea	200
2 auxiliary air and circulating	(Combined) single	Engine	Sea and condensers	400
2 distiller circulating	Horizontal single	Engine	Sea	85
2 evaporator, feed and tank	Horizontal single	Engine	Sea and filter	4
2 evaporator, brine	Horizontal single	Engine	Evaporators	4
1 waste water tank	Horizontal plunger	After uptake	Drainage tanks	40
2 hydraulic	Horizontal duplex	Hydraulic	Accumulator tank	500
1 oil	Horizontal duplex	Engine	Oil tanks	5

There are eight pumps with bilge connections having an aggregate capacity of 2,400 gallons per minute, which, added to that of the circulating pumps, makes a total of 20,400 gallons per minute.

Steam Traps.—The separators, jackets, main and auxiliary

steam pipes, radiators and all places where condensed steam can accumulate are fitted with drain pipes and cocks or valves. These drain pipes are connected with fourteen Watson and Müller automatic traps and three Chapman Columbia traps, which discharge into the feed tanks. All traps are provided with by-pass pipes and valves for convenience in overhauling.

Ash Hoists.—In each main fire room hatch there is a Williamson double, reversible ash hoist, by means of which one bucket of ashes of 300 pounds (with a steam pressure of 60 pounds) can be hoisted in 5 seconds. The steam cylinders are 4½ inches in diameter, with a piston stroke of 4½ inches.

Grease Extractors.—There is a grease extractor in each feeding fire room. It is similar to a Macomb strainer; the basket is perforated and covered with burlap through which the water filters. By-pass pipes and valves are fitted to feed the boilers while overhauling the extractor.

Feed Tanks.—There is a feed tank, of 1,000 gallons capacity, in each engine room. A part of the tank is fitted as a filter into which the water from the air pumps is delivered. The filter is provided with sponges, which are readily accessible. Each tank has a man-hole, glass water gauge, shut-off cocks, and drain cocks. An overflow pipe is fitted and so arranged that any water passing down it may be seen. Each feed pump suction is provided with a balanced valve operated by a copper float in the feed tank and so arranged that no air will enter the feed pipes.

Workshop —The workshop is situated on a platform in the after part of the engine rooms. It is fitted with a vertical engine, 6 inches by 6 inches, a lathe, a shaping machine, a double-geared drilling machine, a grind stone and an emery wheel.

Distilling Apparatus.—There are two Baird distillers and two Baird evaporators with a maximum distilling capacity of 5,500 gallons of potable water in twenty-four hours; the ordinary capacity is 4.000 gallons. A Davidson pump (steam cylinder, 4½ inches diameter; water cylinder, 5 inches diameter; stroke, 8 inches) is used to circulate the water through the distillers. After leaving the distillers the circulating water passes through the flushing pipes, and by-pass valves and pipes are fitted so that

the water can enter the flushing pipes without passing through the distillers. A horizontal combined pump is used to feed the evaporators and to deliver the water from the filters to the ship's tanks; it has a steam cylinder 2½ inches diameter, water cylinders 1½ inches diameter, and a stroke of 3 inches. There is a pump to deliver the drain water from the evaporators into the feed tank; it has a steam cylinder 2½ inches diameter, a water cylinder 1½ inches diameter, and a stroke of 3 inches.

Steam Cutters.—There are two steam cutters, one 33 feet, and the other 30 feet long. They have Towne boilers, compound engines and keel condensers. The cylinders for the 33-foot cutter are 4 inches and 7 inches diameter by 7 inches stroke, and those for the 30-foot cutter, 3½ inches and 7 inches diameter by 6 inches stroke.

Telegraphs and Revolution Indicators.—There is a Cory mechanical telegraph in each engine room connected to transmitters in conning tower, pilot house and bridge, and a mechanical gong in each engine room with bell pulls at the steering wheels at after part of the superstructure deck. Mechanical tell-tales are fitted on the bridge and in the conning tower to show the direction of revolution of the main engines. In each engine room there are two mechanical indicators to show the speed and direction of revolution of each propeller. The two indicators are connected and each has two hands, a red one which turns with the port engine, and a green one which turns with the starboard engine. The hands can be turned on their shafts like the hands of a clock, so that by setting them together the relative speeds of the propellers can be seen as the hands separate or remain together in their revolutions over the dial of the indicator.

Telephones and Voice Pipes.—For communication between the various parts of the ship there is a complete system of telephones, and voice pipes with call bells. The most important stations are connected direct with voice pipes, but for general purposes, in order to lessen the number of pipes, a central station is used.

Steering Engine.—On the after platform deck there is a Williamson combined hand and steam steering engine; cylinders, 13 inches diameter; stroke, 10 inches. The engine is connected to

a horizontal fore-and-aft shaft, on the after end of which is a right-and-left-hand screw. The screw works in two crossheads, one on the starboard and one on the port side, and the rudder yoke is connected by rods to these crossheads. With the steam gear, the rudder can be put hard over from amidships in 10 seconds when the ship is going full speed.

Steam Windlass.—On the main deck forward there is a steam windlass, built by the American Ship Windlass Company. The engine is reversible, double cylinder, vertical, direct acting, with cylinders 15 inches in diameter, and a stroke of 14 inches. The windlass is fitted with four wild cats to take the chains, also two drums or gypsies to take hawsers.

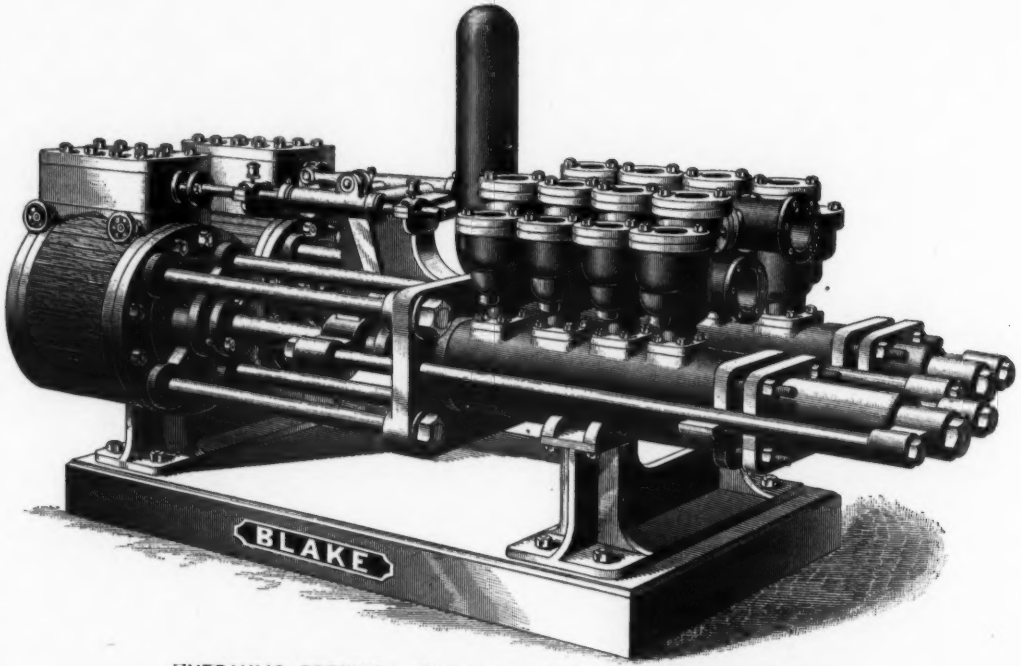
Steam Winches.—There are four double cylinder Williamson reversible winches or hoisting engines situated on the main deck, two forward and two aft. Each has one drum for wire rope and two gypsies for hawsers. Steam cylinders, 8 inches diameter, stroke, 8 inches. There are also two winches, of the same size as the above, situated on the superstructure deck, for hoisting boats.

Ice Machine.—There is an Allen dense air machine with a normal capacity of one ton of ice per day, or 200 pounds of ice and at the same time keeping the refrigerating rooms near the freezing point, and cooling 300 gallons of water to 40 degrees Fahrenheit. Steam cylinder, 7 inches diameter; air compressor cylinder, $5\frac{3}{4}$ inches diameter; air expansion cylinder, $4\frac{3}{4}$ inches diameter; stroke, 10 inches. The circulating water and primer pumps are single acting, each $1\frac{5}{8}$ inches diameter and 10 inches stroke.

The following are the results of a five hours' trial of the ice machine for this vessel.

The machine was started at 2 P. M., January 15, 1895, on brine tank, cooling chloride of calcium; at 2.30 P. M. it was turned on the refrigerating rooms and scuttle butt, and at 6.30 P. M. on the whole system, running continuously thereafter until the end of the trial at 2.30 P. M., January 16th.

Time.	Steam pressure per gauge.	Revolutions per minute.	Pressure per gauge in air compressor cylinder.	Pressure per gauge in air expander cylinder.	Temperature refrigerating compartment, degrees Fahrenheit.					Pounds of ice.	Scuttle butt.				Temperature of atmosphere, degrees Fahrenheit.
					Room No. 1.	Room No. 2.	Room No. 3.	Room No. 4.	Mean.		Temperature, degrees Fahrenheit.	Gallons water drawn off.	Time of drawing water.	Temperature of water put in, F°.	
9 30 A. M....	62	122	255	80	3	1	3	1	.5	.....	32	.....	.....	40	85
10.00	63	120	255	80	2	0	3	0	.25	.....	32	30	9 48 to 10 00	40	85
10.30	63	121	255	80	0	0	3	−1	.5	32	34	.....	.....	40	85
11.00	63	121	255	80	−4	−2	1	−1	−1.5	32	34	30	10.37 to 10 45	40	87
11.30	60	122	254	80	−2	1	2	0	.25	32	34	30	11.18 to 11 25	40	86
12.00	60	122	255	80	−2	−2	3	1	0	32	.....	.....	.....	40	86
12.30 P. M.....	57	119	253	80	−2	−1	3	1	.25	.....	33	36	12 00 to 12 10	40	86
1 00	61	124	255	80	−2	−1	3	1	.25	32	33	30	12 40 to 12 50	40	89
1.30	64	131	262	81	−2	−1	2	1	.0	.....	33	30	1.10 to 1.20	40	88
2.00	65	130	260	80	−2	−1	3	1	.25	32	33	30	1.40 to 1 50	40	85
2.30	67	134	265	81	−2	−1	3	0	.0	48	33	30	2 10 to 2 20	40	87
Average per hour.	62.3	124.2	256.7	80.2	-2.1	- 63	2.64	.36	.07	48	33 1	49.2	.....	40	86.3
Rate per 24 hours.	.....	.....	.....	.....	.....	.....	.....	.....	.07	1.152	33 1	1,180.8	.....	.....	.....
Contract per day.	.....	.....	.....	.....	.....	.....	.....	.....	About 32	200	Nearly 40	300	.....	.....	.....



HYDRAULIC PRESSURE PUMPS OF U. S. S. "MASSACHUSETTS."

MADE BY THE GEO. F. BLAKE MANUFACTURING CO., NEW YORK.

Thirteen-inch Turret Turning Machinery.—Each 13-inch turrret is turned by a double, horizontal engine, with cylinders 11½ inches diameter and 10 inches stroke. One engine is located in the compartment forward of the boilers, the other in the compartment abaft the engines. The turrets are turned by means of shafting and gearing, pinions on the top of the vertical shafting engaging a rack on the bottom of the turret. Each engine has a controlling valve, which is worked by means of shafting and gearing, from the sighting hoods of the turret, the arrangement being such that the gear in the auxiliary sighting hood can be disengaged at the will of the operator in the main sighting hood. Each turret can be turned through an angle of 270 degrees, and in order to prevent it from turning beyond its limits, an improved automatic stop gear is provided which acts on the controlling valve. Provision is also made for turning by hand.

Eight-inch Turret Turning Machinery.—Each 8-inch turret is turned by a double, vertical engine, with cylinders 8 inches diameter and 7 inches stroke, located in the ammunition passages on the orlop deck. A worm on the crank shaft of the engine engages a worm wheel on the lower end of the ammunition tube. Each engine is provided with a controlling valve, which can be operated at the engine, and also from the sighting hoods of the turrets by means of shafting and gearing. Automatic stop gear is provided to prevent the turrets from turning too far. In case the engine becomes disabled, provision is made for turning by hand.

Air Compressors.—There are two Rand air compressors for torpedo tubes situated on the orlop deck within the citadel, one forward and one aft. Each compressor has two steam cylinders, diameter, 9 inches, stroke, 4 inches. The air cylinders are above the steam cylinders and are enclosed in a chamber through which water circulates. The compressors are capable of making 200 revolutions per minute with 50 pounds steam pressure, the air pressure in the accumulator being 1,700 pounds to the inch.

Hydraulic Plant.—There is an hydraulic plant situated forward on the orlop deck within the citadel. It is used to elevate and depress the 13-inch guns, to load the guns, and also to hoist the ammunition for them. It consists of two horizontal, double act-

ing duplex Blake pumps, an accumulator water tank, and the necessary piping. The combined capacity of the pumps is 1,000 gallons per minute, the working pressure being 600 pounds per square inch. This duty is done with 100 pounds steam pressure at the pump throttles. There is an accumulator consisting of a steam cylinder, a steam piston, and a water plunger. The steam piston is connected by means of shafting and levers to the throttle valves of the pumps.

The water tank has a capacity of 200 gallons, and fresh water only is used.

The delivery pipes are 4 inches in diameter and of wrought steel; the return pipes are 6 inches in diameter and of wrought iron. The flanges of the pipes are turned male and female and the joints made with leather gaskets. The delivery and return pipes lead to a double composition pipe casting around which a composition chamber revolves. The revolving chamber turns with the turret; it is divided into pressure and exhaust passages, and the joints are made with cup-leather packing. The delivery and return pipes from the cylinders, for working the guns and hoisting the ammunition, are connected to the revolving chamber. All parts of the hydraulic system, except the suction, were tested to 1,200 pounds water pressure.

Steam cylinders, number	4
diameter, inches	24
stroke, inches	12
Water plungers, number	4
diameter, inches	8
stroke, inches	12
Accumulator steam cylinder, diameter, inches	28
water plunger, diameter, inches	10
stroke, inches	30

Electric Plant.—The installation consists in general of three generating sets, 590 incandescent lights, 4 search lights, 1 set of signalling apparatus, 2 stationary ventilating fans driven by electric motors, 4 portable ventilating fans driven by electric motors, 4 electric motors for 8-inch ammunition hoists, 2 electric motors for 6-inch and secondary battery ammunition hoists and 1 main

switch board, together with the necessary wire, wiring accessories, molding and fixtures.

The generating sets were made by the General Electric Company at Schenectady, N. Y. In each set there is a 24-kilo-watt dynamo of the multipolar type, having a capacity of 300 amperes at 80 volts, compound wound on 144 armature sections, cross connected at 180 degrees. The engines driving the dynamos are two-cylinder, vertical, inverted; diameter of cylinder, 10½ inches; stroke, 5 inches. The crank shaft and armature shaft are connected by a rigid coupling. The engines are designed to run, with full load, at 400 revolutions per minute with 80 pounds steam pressure. The bed plate is common to both engine and dynamo and measures 7 feet 3 inches by 3 feet 10 inches. The weight of each generating set (engine, dynamo and bed plate) is about 8,500 pounds. The incandescent lights are 16 and 32-candle power designed for 80 volts.

There are four search lights, made by the General Electric Company; two mounted on the top of the pilot house, and two mounted in hammock berthing near the after end of the fore-and-aft bridge. The projectors are 60 centimeters in diameter and electrically controlled. All lamps are horizontal combination, hand or automatic, and designed for a current of 80 amperes at about 50 volts. The carbon holders are adjustable, and the life of the carbon is 6 hours. Each search light has a power of about 25,000 candles.

The signal apparatus consists of four double signal lanterns, cable connection and key board. Each half of each double lantern is fitted with a fresnel lens, the upper lens being red. The key board is arranged to admit of thirty combinations of lights being made, each combination requiring but one motion to close the circuit.

There are two stationary ventilating fans, one arranged to force air into, and the other to exhaust the air from the dynamo room. Each fan is capable of delivering 2,200 cubic feet of air per minute at a speed of 1,570 revolutions, and is connected directly to a 2-horse power electric shunt motor.

There are four portable fans, to be used to exhaust the air from the double bottoms and various compartments. Each fan is

capable of delivering 400 cubic feet of air per minute at a speed of 1,863 revolutions, and is directly connected to a ¼-horse power electric series motor.

There is a standard Navy switchboard complete, containing the necessary connections, switches, cut-outs, &c., for 9 incandescent, 4 search light, and 3 motor circuits. It is provided with a pressure board, ground detector and measuring instruments. The pressure board has points connecting the volt meter with the terminals of each of the dynamos, and with each of the search light circuits. The ground detector is arranged to be thrown on either arc or incandescent circuit when operated separately.

Electric speed indicators and transmitters are fitted on the bridge, pilot house and in conning tower; also electric helm indicators.

There are water alarms in each bilge compartment, and thermostats in each coal bunker and paint room, with annunciators on bulkhead forward of cabin.

There are four 6.7-horse-power electric motors for hoisting the ammunition for the 8-inch guns, and two 5-horse-power motors for the ammunition hoists that supply the 6 inch guns and secondary battery.

The following lights are provided for:

Deck lanterns,	85	single.
Portable hand lamps,	118	"
Ceiling ring lamps,	102	"
Bulkhead lights,	58	"
Coal bunker lights,	68	"
Steam tight globes,	20	"
Desk lights,	40	"
Magazine lanterns,	36	double.
Signal lights,	15	"
Truck lights,	1	"
Masthead and towing lights,	2	"
Cargo reflectors,	4	quadruple.
Running lights,	2	single.
Electroliers,	3	triple.
	554	

Of the above lights, the following are distributed in the main engine and boiler rooms:

Bulkhead lights,	11
Steam tight globes,	11
Portable hand lamps,	59
Ceiling ring lamps,	4
Coal bunker lights,	16
	101

These rooms are also provided with a complete set of bulkhead lamps for burning oil, for use in case of failure of the electric lights.

LIST OF ENGINES ON BOARD THE *MASSACHUSETTS.*

Main Engines.

	No. of steam cylinders
2 propelling engines, vertical, triple expansion,	6

Main Engine Auxilaries.

2 main air pumps, Blake, vertical twin,	4
2 centrifugal circulating pumps, horizontal,	2
2 auxiliary air and circulating pumps, Blake, combined, horizontal,	2
2 reversing engines, main engines, vertical,	2
2 turning engines, main engines, vertical,	4
4 main feed pumps, Blake, vertical, duplex,	8
4 auxiliary feed pumps, Blake, vertical, duplex,	8
2 main feed pumps for auxiliary boilers, Blake, vertical, duplex,	4
2 auxiliary feed pumps for auxiliary boilers, Blake, vertical, duplex,	4
2 water-service pumps, Blake, vertical, duplex,	4
10 forced-draft blowers, Sturtevant, vertical,	20

General Auxiliaries.

6 evaporator and distiller pumps, Davidson, horizontal,	6
2 fire, feed and bilge pumps, Blake, vertical, duplex,	4
2 fire and bilge pumps, Blake, vertical, duplex,	4

2 ventilating blowers, engine room, Sturtevant, vertical,	4
4 ventilating blowers for ship, Sturtevant, vertical,	8
3 dynamo engines, vertical,	6

Special Auxiliaries.

1 workshop engine, vertical,	1
1 steering engine, Williamson, horizontal,	2
4 ash-hoisting engines, Williamson, vertical,	8
1 capstan and windlass engine, vertical,	2
6 steam winches, Williamson, horizontal and inclined,	12
2 hydraulic pumps, Blake, horizontal, duplex,	4
1 steam hydraulic accumulator,	1
2 13-inch turret-turning engines, horizontal,	4
4 8-inch turret-turning engines, vertical,	8
1 ice machine, horizontal,	1
2 Rand air compressors, for torpedo tubes,	4
1 waste water tank pump, Blake, plunger, horizontal,	1
1 oil pump, Blake, horizontal, duplex,	2
2 propelling engines, steam cutter, compound, vertical,	4
2 feed pumps, steam cutter, Worthington, vertical,	4
Total number of engines,	86
Total number of steam cylinders,	158

As the *Massachusetts* is a counterpart of the *Indiana* in almost every respect, much of the detailed description and data here given has been taken from the report of the trial of the latter vessel, prepared by Passed Assistant Engineer Harry Hall, U. S. Navy, and published in Volume VII, No. 4, of this JOURNAL, changes having been made where they were found necessary.

OFFICIAL SPEED TRIAL.

The ship left the works of the contractors on Saturday, April 18, 1896, and proceeded to Boston, Mass., where a preliminary run over the trial course took place on April 23. The next day was devoted to making preparations for the official run, and in giving the men as much rest as possible, in order that they might be most thoroughly fitted for the arduous duties before them.

The contractors' engineer force for the trial consisted of 128 men, distributed as follows:

6 engineers; 4 water tenders; 4 stokers; 1 night engineer; 16 engine room oilers; 32 day firemen; 24 day coal passers; 5 night firemen; 4 night coal passers; 4 spare firemen; 2 spare coal passers; 6 messmen; 1 store keeper; 1 time keeper; 5 machinists; 2 riggers; 3 boiler makers, and 8 oilers for fire room blowers.

On Saturday, April 25, 1896, the official trial was made over the Cape Ann course. It consisted of two runs, in opposite directions, over a measured distance of 31 nautical miles, six vessels being stationed at equal intervals along the course, to note the times of passing and make tidal observations. The sea was smooth, with a light E.S.E. breeze, and all the conditions for the trial were most favorable.

An addative average tidal correction of .0679 knots was calculated by the observers on the vessels at the different stations along the line, making the official average speed 16.2079 knots, and the premium earned $100,000.

All the boilers were in use under forced draft; the auxiliary boilers being used for the dynamo, steering engine and other auxiliary machinery only. During the trial the boilers operated admirably in all respects, steaming steadily and without any tendency to prime. The main engines worked excellently. There was no heating of consequence, and very little water was used, although an abundance of oil was constantly supplied. The main air pumps performed their duty so efficiently and thoroughly that their special merits, now so universally acknowledged, were again demonstrated. All the other auxiliaries worked effectively and well, running continuously and uniformly throughout the trial. A careful examination of the cylinders, valves and bearings of the machinery, and of all boilers, was made after the trial and all parts were found in good condition.

DATA OF OFFICIAL TRIAL.

Draught, mean for trial, forward, feet	23.79
aft, feet	24.38
Displacement at mean draught on trial, tons	10,265

Area of immersed midship section, square feet	1,545
Wetted surface, square feet	30,360
I.H.P. (total) per 100 square feet of wetted surface	34.30
at 10 knots, reduced in ratio of 3.5 power	6.33
Average speed in knots	16.2079
Slip (mean of both screws), per cent	22.64
Speed ^{3} × area of immersed midship section ÷ I.H.P.	643.50
Speed ^{3} × displacement $^{\frac{2}{3}}$ ÷ I.H.P.	197.66

SYNOPSIS OF STEAM LOG.

	Starboard.	*Port.*
Revolutions of main engines per minute, mean	132.30	133.06
Piston speed in feet, per minute	926.10	931.42
Steam pressure at boilers, per gauge	163.00	
engines, per gauge	155.60	
1st receiver, absolute	80.10	74.70
2d receiver, absolute	28.05	27.90
Vacuum in condensers, inches of mercury	25.15	25.20
Opening of throttle	Wide.	
Steam cut-off in fractions of stroke from beginning, H.P.	.673	.673
I.P.	.678	.694
L.P.	.7065	.712
Double strokes of air pump, per minute	15.	18.
Revolutions of circulating pumps, per minute	159.	195.
Temperatures in degrees Fahrenheit, engine room	75.1	71.7
injection	43.5	43.5
discharge	118.2	122.9
hot well	105.7	89.
feed	111.4	113.1
fire rooms	96 43	
Air pressure, in inches of water, in fire rooms	.9935	
Revolutions of blowers per minute, fire rooms	458 09	
engine rooms	262.75	
Mean pressures in cylinders, H.P	56.645	57.495
I.P.	35.455	34.765
L.P.	14.450	14.790
equivalent reduced to L.P.	40.950	40.900
I.H.P.:		
H.P. cylinder	1,453.47	1,484.88
I.P. cylinder	1,783.42	1,756.82
L.P. cylinder	1,813.06	1,836.19
Collective, each main engine	5,049.95	5,077.88
both main engines	10,127.83	
Air pumps	5.17	7.27

I.H.P.:		
Circulating pumps	15.19	21.75
Feed pumps	63.23	
Blowers, forced draft	107.19	
Other auxiliaries	45.03	
Collective I.H.P. of all auxiliaries	274.83	
main engines, air and circulating pumps	10,177.21	
all machinery in operation	10,402.66	
Indicated thrust (main engines only), pounds	78,726.54	78,709.81
per square foot of developed area of propellers, pounds	1,461.71	1,461.40
Indicated thrust per square inch of thrust bearing, pounds	36.14	36.14
Cubic feet swept per minute by L.P. piston per I.H.P.	5.60	5.60
Square feet of cooling surface per I.H.P.	1.298	
total heating surface per I.H.P.	1.84	
I.H.P. per square foot of G.S. (all machinery in operation),	16.9	

The maximum performance was on the last fifteen minute period of the run south, when the main engine and auxiliaries developed 11,440 I.H.P.

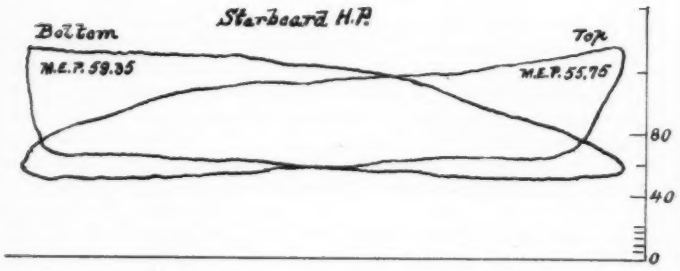
On the return trip from Boston to Philadelphia, all the turret machinery was tried.

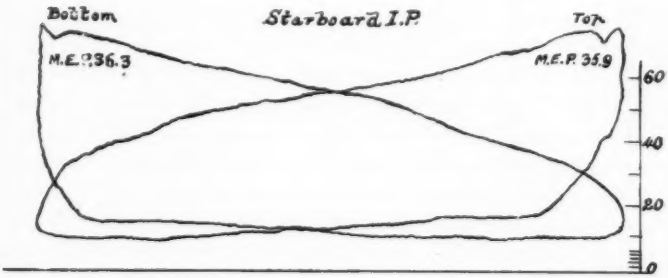
The turrets worked smoothly and efficiently, and the ease with which the 13-inch guns were elevated and depressed, well demonstrated the strength and reliability of the hydraulic pumps which produce the high pressure required for this service.

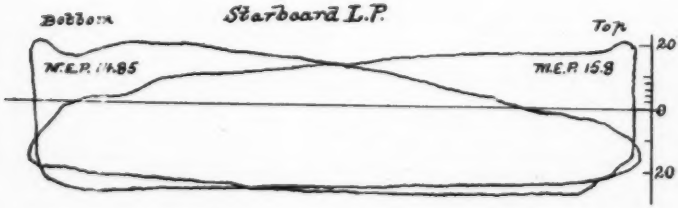
During this passage, on Monday, April 27, 1896, the coal consumption trial took place with the two after boilers in use. Owing to unavoidable circumstances the trial only lasted four hours, and the trial data were considered unsatisfactory:

U. S. S. Massachusetts

Vacuum . . . . . 25.
Revolutions 132.3

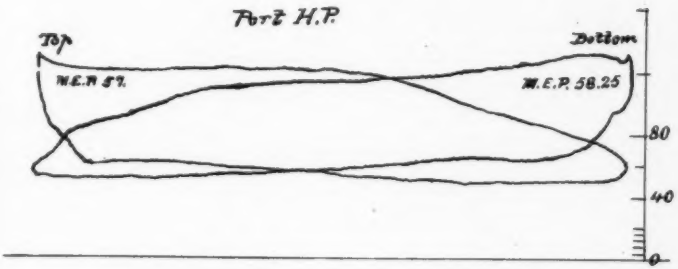


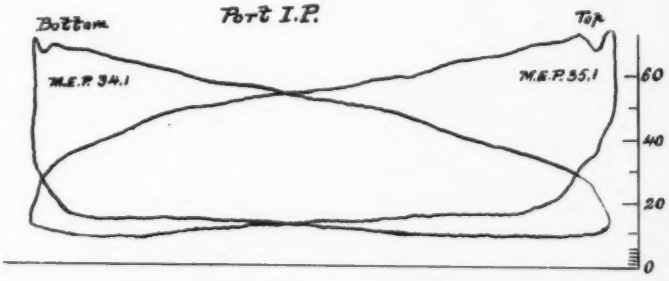


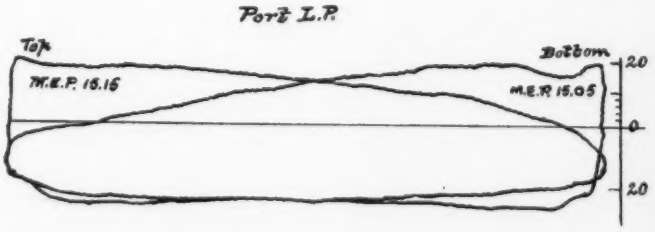


U. S. S. Massachusetts.

Vacuum . . . . . 25.
Revolutions 133.06



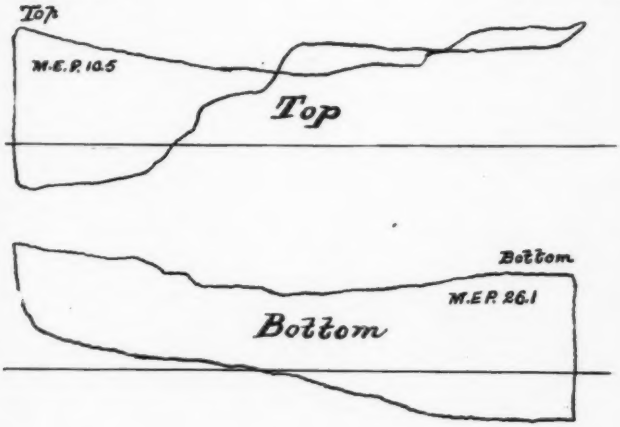




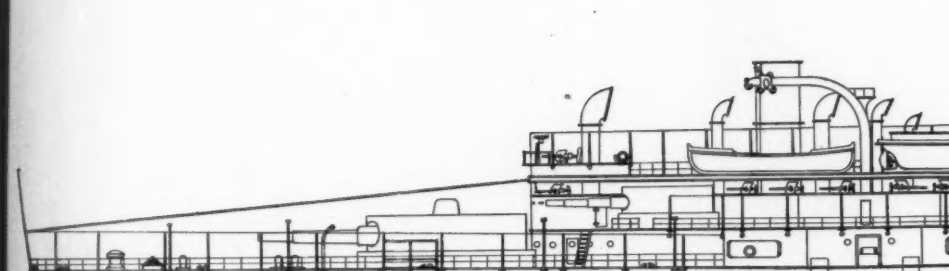
U. S. S. Massachusetts

Starboard Air Pump Cards.

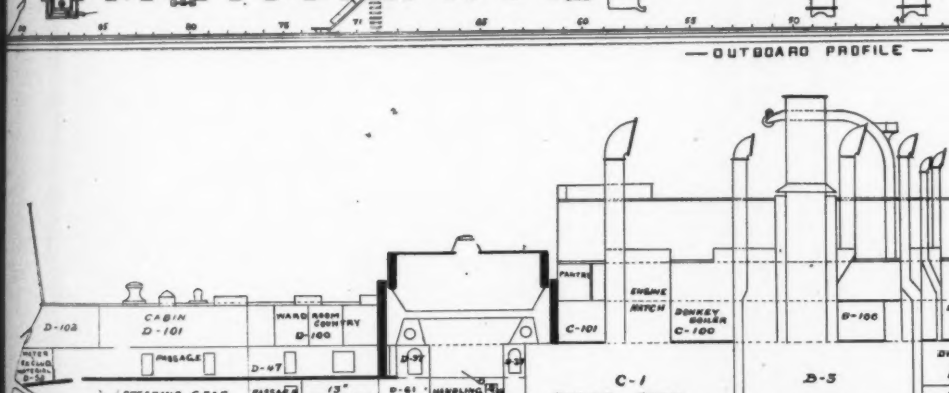
Double Strokes	16.
Vacuum	24.6 ins.
Steam Pressure	155 lbs.
Scale	40 lbs.



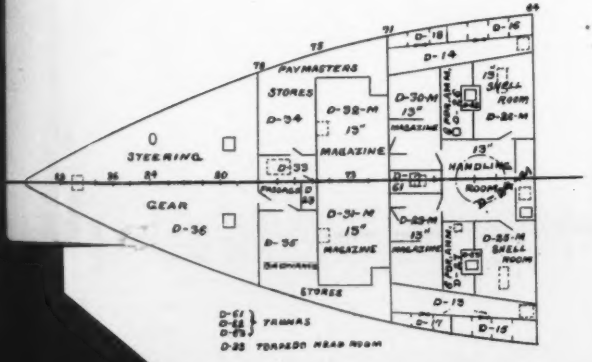
Pump Card, Scale 12.



— OUTBOARD PROFILE —

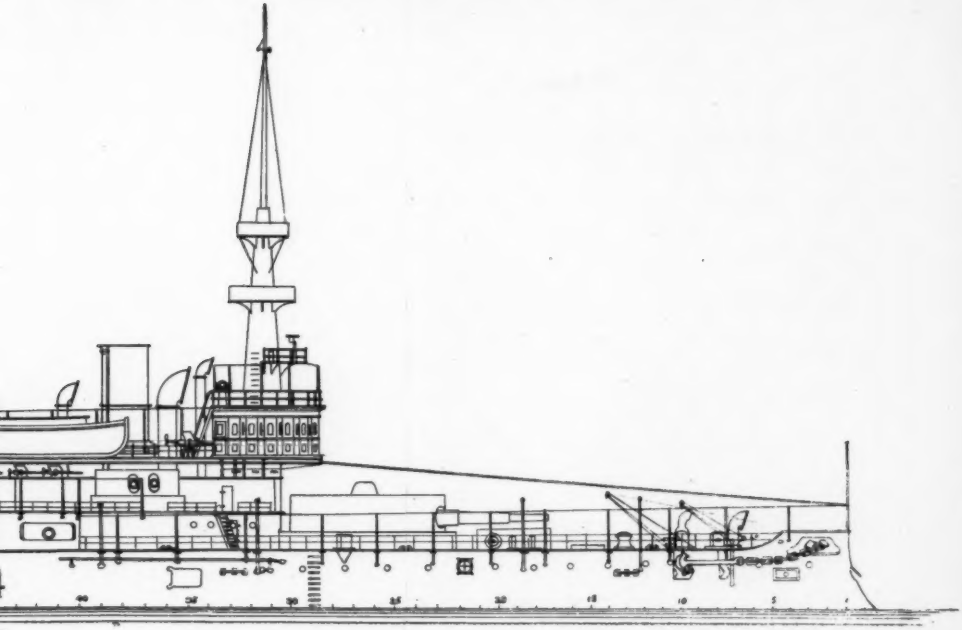


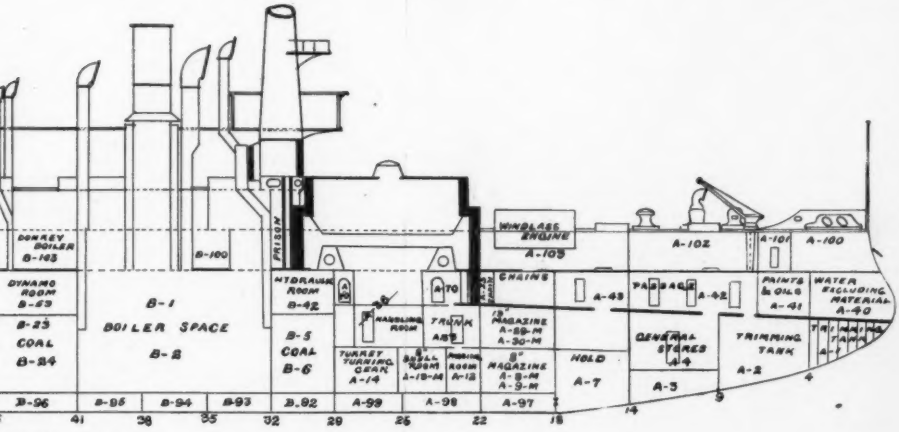
— INBOARD PR



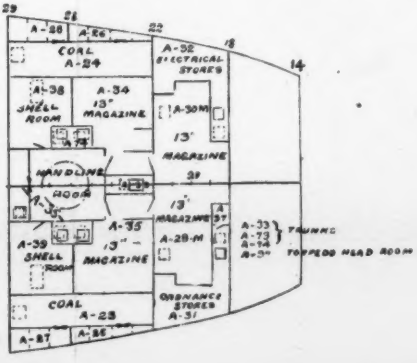
LENGTH BETWEEN PE
LENGTH EXTREME-
BREADTH EXTREME
MEAN DRAFT -----
TONS DISPLACEMENT

— PLATFOR



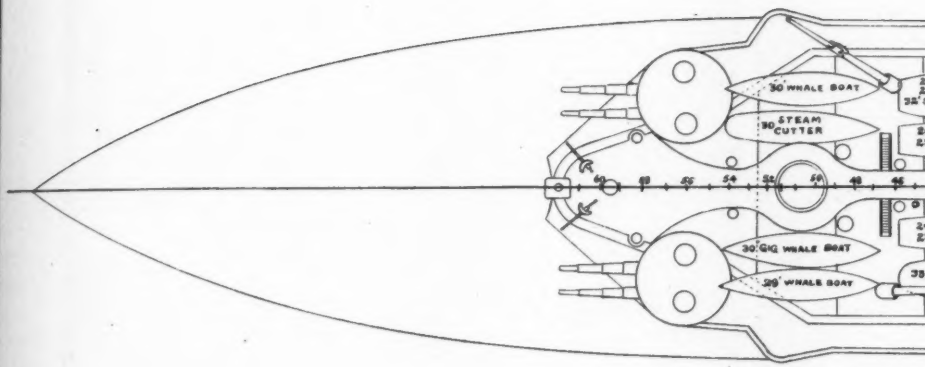


ROFILE —

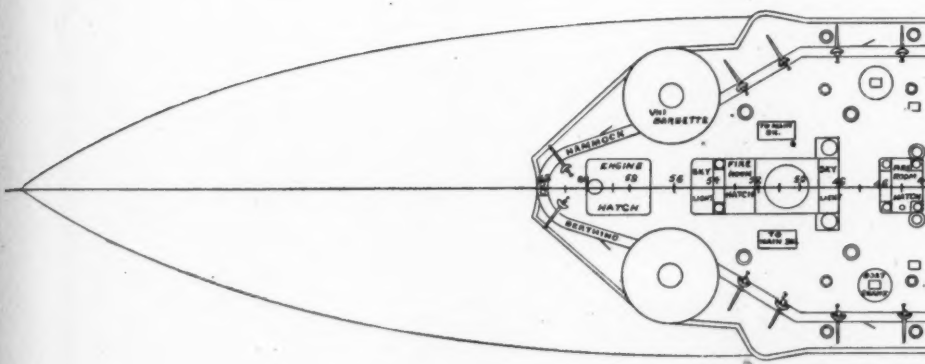


PERPENDICULARS ----- 348 FT.
" ----- 350 "
ME ----- 69 FT. 3 IN.
----- 24 FT.
VT AT 24 FT. W. L ---- 10225.

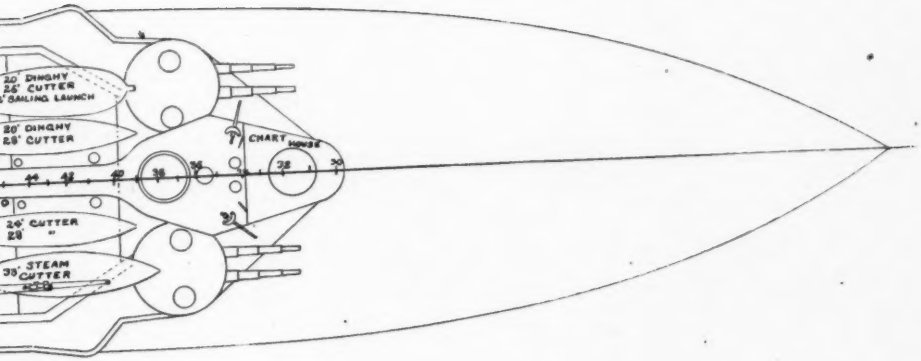
RMS —

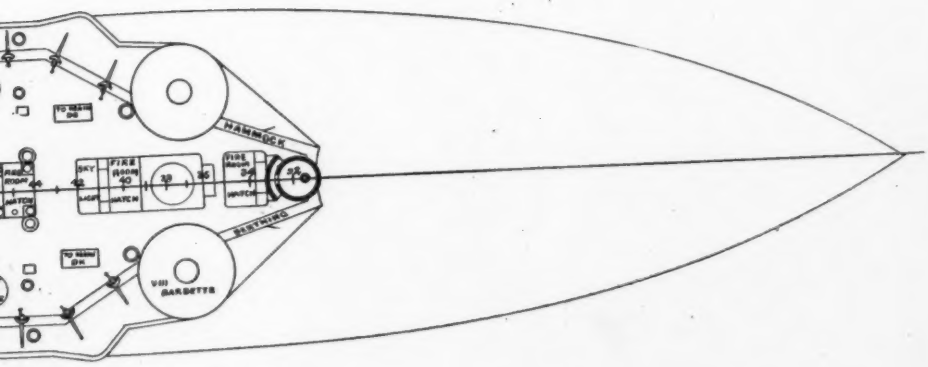


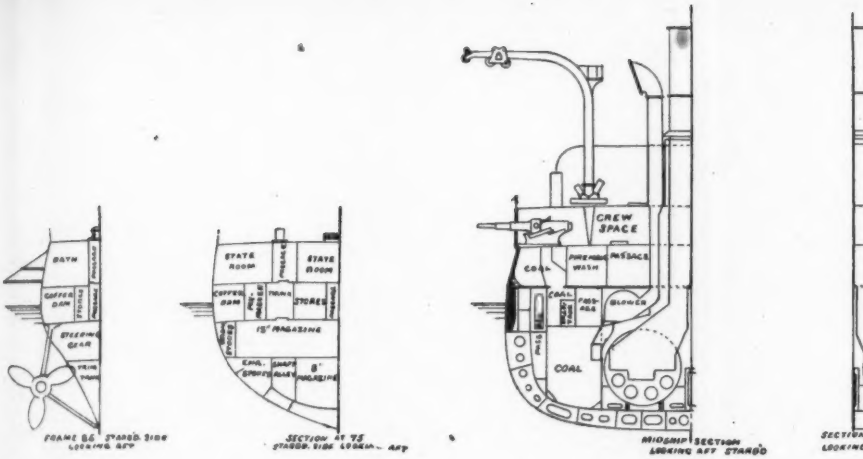
— BRIDGE DEC

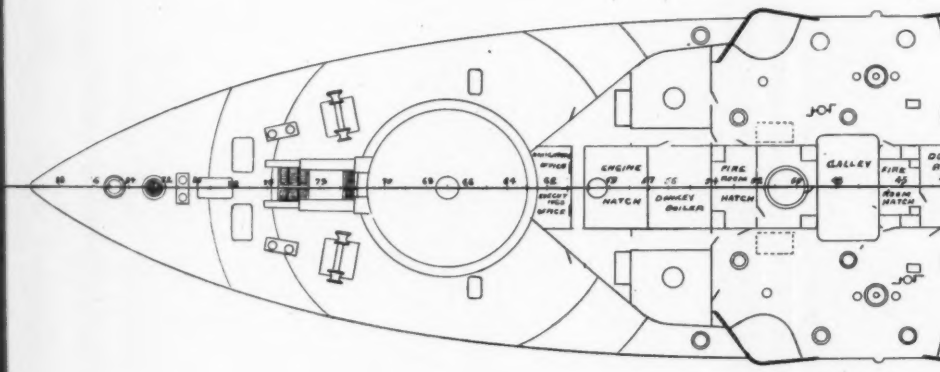


— UPPER DECK

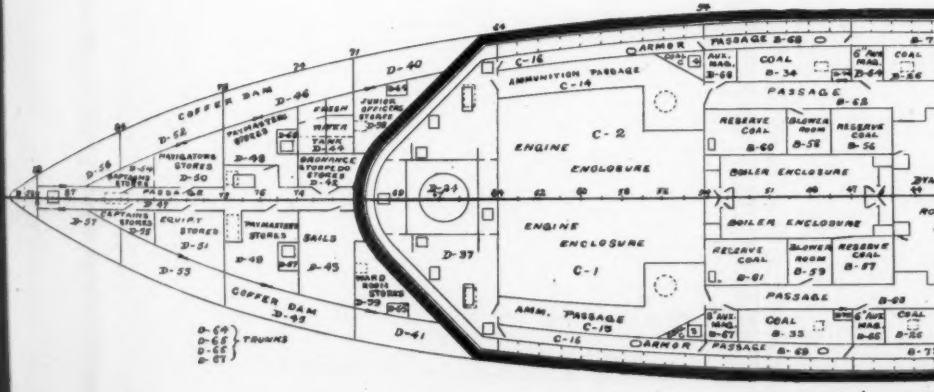

20' DINGHY
25' CUTTER
SAILING LAUNCH
20' DINGHY
28' CUTTER
CHART HOUSE
24' CUTTER
28 "
38' STEAM
CUTTER
ECK —


HAMMOCK
FIRE ROOM
WATCH
BERTHING
VIII BARBETTE
ECK —

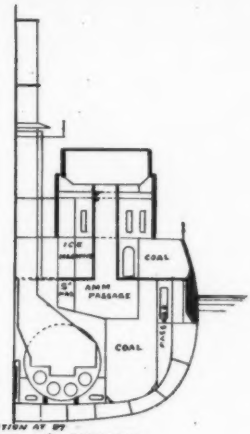




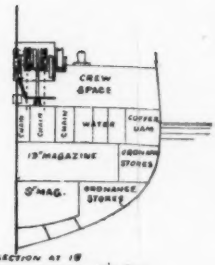
MAIN DECK



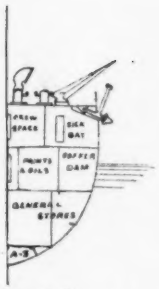
ORLOP DECK



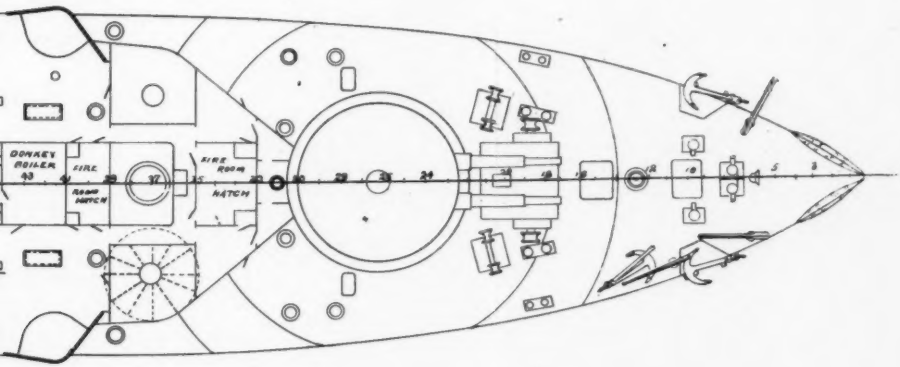
TION AT 97
KING FORD. STARBD. SIDE

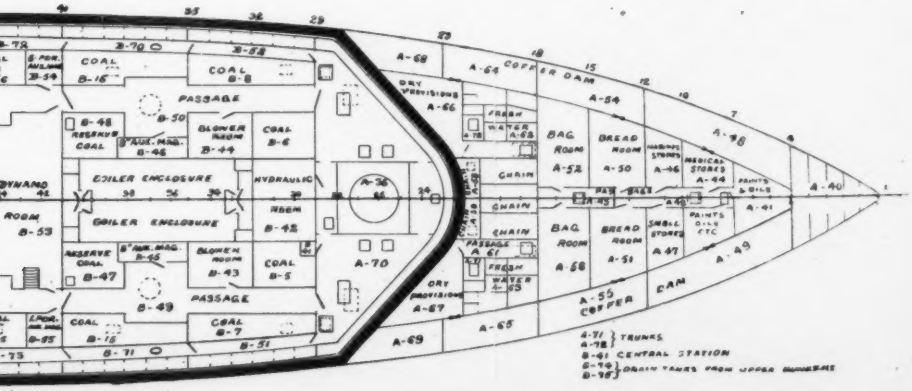


SECTION AT 18
LOOKING FORD. STARBD. SIDE



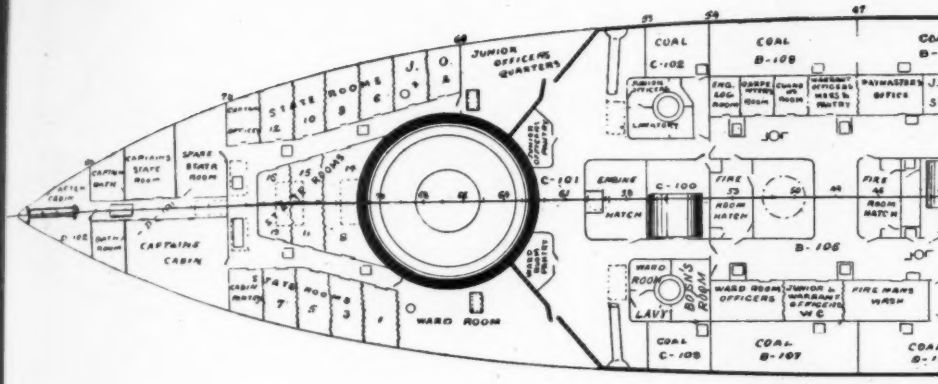
SECTION AT 9
LOOKING FORD. STARBD. SIDE

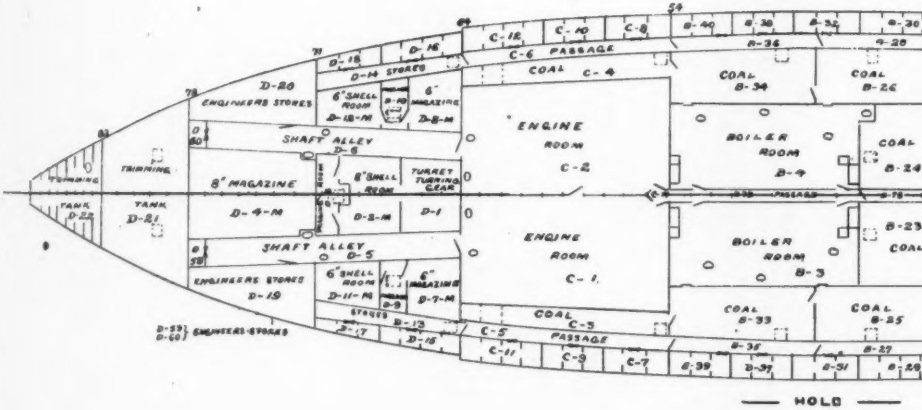


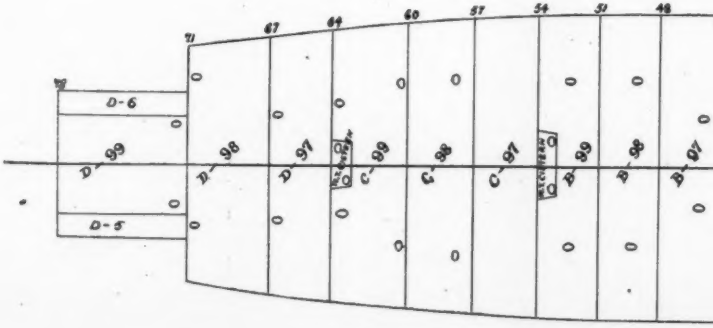


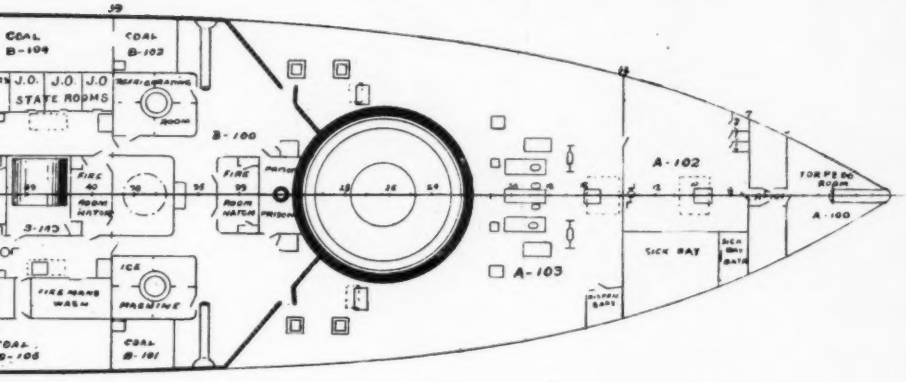
4-71 } TRUNKS
4-72 }
B-61 CENTRAL STATION
B-70 }
B-98 } CHAIN TANKS FROM UPPER MAGAZINE

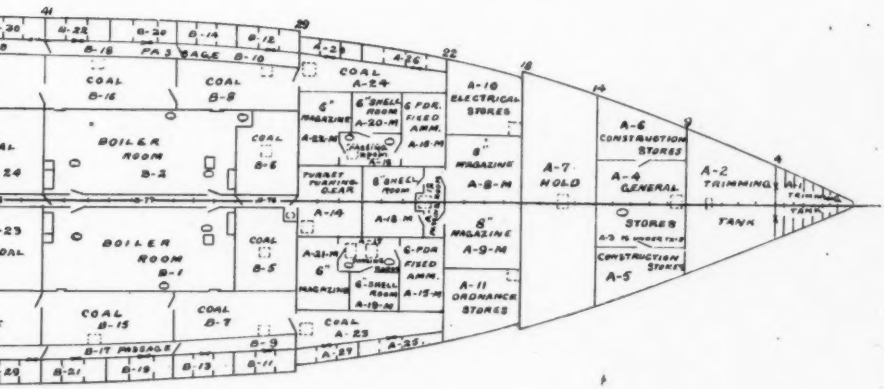
AND PASSAGES

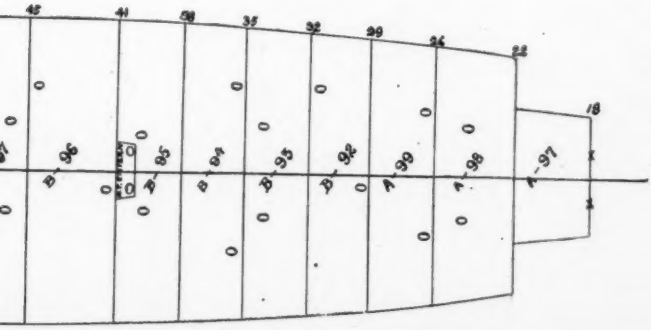

JUNIOR OFFICERS' QUARTERS
CAPTAIN'S CABIN
WARD ROOM
COAL
C-102
COAL
B-108
C-101
ENGINE
HATCH
C-100
FIRE
ROOM
HATCH
B-106
WARD ROOM
LAVY.
BOSN'S ROOM
WARD ROOM OFFICERS
JUNIOR & WARRANT OFFICERS W.C.
FIRE MAINS WASH
COAL
C-103
COAL
B-107
— BERTH DECK —


D-20
ENGINEERS STORES
D-14 STORES
C-12
C-10
C-8
C-6 PASSAGE
COAL C-4
COAL B-34
COAL B-26
ENGINE ROOM C-2
BOILER ROOM B-4
8" MAGAZINE
SHAFT ALLEY D-6
TURRET TURNING GEAR
D-4-M
D-3-M
D-1
SHAFT ALLEY D-5
ENGINEERS STORES D-19
ENGINE ROOM C-1
BOILER ROOM B-3
COAL C-3
COAL B-33
COAL B-25
C-5 PASSAGE
C-11
C-9
C-7
— HOLD —


D-6
D-99
D-98
D-97
C-99
C-98
C-97
B-99
B-98
B-97
D-5
— INNER BOTTOM —


COAL B-104
COAL B-103
J.O. J.O. J.O
STATE ROOMS
B-100
FIRE ROOM
FIRE ROOM
A-102
TORPEDO ROOM
A-100
A-103
SICK BAY
ICE
PARENTINE
FIRE MAINS WASH
COAL B-106
COAL B-101


COAL B-16
COAL B-8
BOILER ROOM B-2
BOILER ROOM B-1
COAL B-15
COAL B-7
COAL A-24
COAL A-23
6" MAGAZINE A-20-M
6" SHELL ROOM
6 POR. FIXED AMM.
TURRET TURNING GEAR
A-10 ELECTRICAL STORES
6" MAGAZINE A-8-M
6" MAGAZINE A-9-M
A-11 ORDNANCE STORES
A-7 HOLD
A-6 CONSTRUCTION STORES
A-4 GENERAL
A-2 TRIMMING TANK
STORES
CONSTRUCTION STORES A-5


B-96
B-95
B-94
B-93
B-92
A-99
A-98
A-97

NAVAL SOCIETY

FORMULÆ FOR THE STRENGTH OF SEAMS, STAYS AND BRACES FOR CYLINDRICAL BOILERS.

By Chief Engineer A. B. Canaga, U. S. Navy.

The disposition of the least amount of material to withstand safely the high steam pressure required for the economic working of triple and quadruple expansion engines is one of the problems met by the marine engineer in designing a cylindrical boiler. And since the pressure in such a boiler produces the greatest stress to rupture along the longitudinal seams, these seams will be the first and most careful consideration.

In order that the seams of a cylindrical boiler may be safe, and yet have the material properly distributed, it will be necessary to so proportion the thickness and lap of the shell sheets, the diameter and pitch of the rivets, that the shell shall be on the point of tearing asunder between the rivets just as the plate in front of the rivets and the rivets themselves are about to give way by crushing.

The tightness of the seam will be insured when the elements of the seams are proportioned for greatest strength to resist the bursting pressure.

The seams generally met with in cylindrical boilers for marine use will be the ones here considered. These are single-riveted lap seams; double-riveted lap seams; double-riveted butt seams with double butt straps; triple-riveted butt seams with double butt straps, and welded seams. The last named, though theoretically the most efficient, has met with least favor, owing to the lack of confidence in its integrity.

Could a welded seam be made perfect, the thickness of a cylindrical shell of a boiler to withstand safely the working pressure could be determined from the formula,

$$P \times r = t \times \frac{T}{4.5}$$

or

$$t = \frac{4.5 \times P \times r}{T} \qquad (1)$$

t = thickness of shell sheet in inches.
T = ultimate tensile strength of shell sheet in pounds per square inch.
r = radius of shell in inches.
P = safe working pressure of steam per square inch per gauge.
4.5 = factor of safety.

As equation 1 is a fundamental one it will be well to look to its accuracy. Assume the lower half $ABCD - E$, Fig. 1, of the ring or cylindrical section of the shell to be fixed. Then, if the pressure inside the ring be increased to overcome the ultimate strength of the material, the half $ABCD - G$ will be torn from the fixed or lower half, the rents coming at AD and BC, the intersections of the plane $ABCD$ through the axis of the cylinder, separating the fixed and the free halves of the ring. Omitting the factor of safety 4.5 and assuming P' to be the bursting pressure per square inch, equation 1 becomes

$$P' \times r = t \times T \qquad (2)$$

The pressure acts radially from the center O, as indicated by the arrows in Figure 2, and the vertical component of the total pressure on the upper or free half is the part of the bursting pressure effective in tearing it from the fixed half. The pressure along OA and OB has no vertical component, while along OG the vertical component is equal to the pressure P' per square inch, that is it is at its maximum. The total vertical component is found by taking the sum of all the elementary vertical components. The elementary radial pressure, making the angle θ with OB, will act on the elementary surface $rd\theta \times l$, where

r = radius of the ring in inches.
l = axial length of the ring in inches.

Since, at the instant of bursting, the pressure per square inch is P', the total bursting pressure on the elementary strip of the ring will be $P' \times rd\theta \times l$. And the vertical component of this pressure will be $P' \times r \sin \theta d\theta \times l$.

Therefore, the total vertical bursting pressure

Fig. 1.

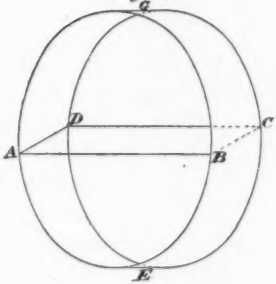


Fig. 2.

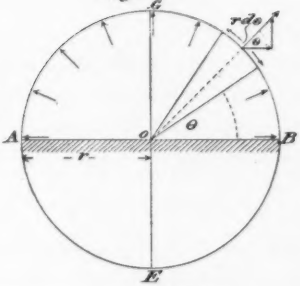


Fig. 3.

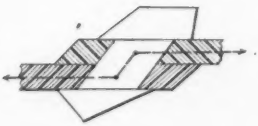


Fig. 4.

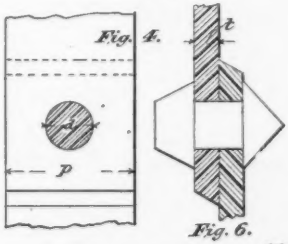


Fig. 5.

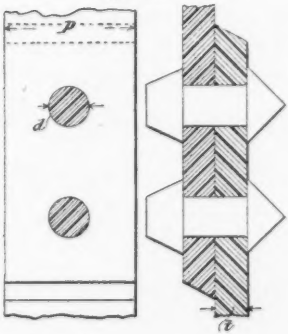
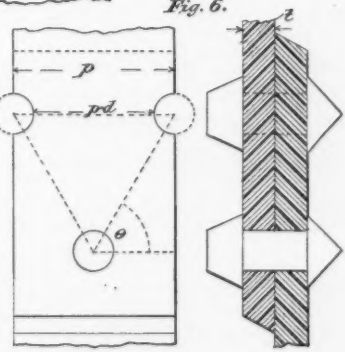


Fig. 6.



$$= P'lr \int_{\pi}^{0} \sin\theta d\theta$$
$$= P'lr[-\cos\theta]_{\pi}^{0} = P'lr[(+1)-(-1)]$$
$$= P'l \times 2r \qquad (3)$$

The square inches of material to be ruptured along the rents AD and BC, Fig. 1, by the bursting pressure will be $2 \times t \times l$. Each square inch will require T pounds to tear it asunder. The ring will, therefore, have a total strength to resist the bursting pressure of

$$2 \times t \times l \times T \qquad (4)$$

At the instant of rupture, the bursting pressure must just equal the ultimate strength of the ring to resist rupture along the lines AD and BC. This condition is fulfilled when equations 3 and 4 are equal, that is

$$P' \times l \times 2r = 2t \times l \times T$$
$$P' \times r = t \times T \qquad (5)$$

which is the same as equation 2.

Introducing the factor of safety in equation 5, P' becomes P, giving

$$P \times r = \frac{t \times T}{4.5} \qquad (6)$$

showing that equation 1 is reliable for a perfectly welded seam.

The pressure to which a boiler should be tested ought not to produce a stress in the material beyond its elastic limit, which for steel is about one half its ultimate strength, or $\frac{T}{2}$. This value substituted in place of $\frac{T}{4.5}$ in equation 1 will give the test pressure,

$$P = \frac{t \times T}{2 \times r} \qquad (7)$$

which will prove the material to its elastic limit. In practice, the stress to which the material of the shell is subjected should be kept well within the elastic limits to avoid the chance of damage.

From experiments, it has been found that the shearing strength of mild steel used in boiler construction averages about four-fifths its tensile strength; and also, that a rivet in double shear is only

one and three-fourths times as strong as the same rivet in single shear, or, more properly, a rivet in single shear is four-sevenths as strong as the same rivet in double shear. This difference is due to the stresses in the overlapping sheets of a lap seam forming a couple, (as shown in figure 3,) which produces a combination of shearing and tension before the destruction of the rivet. And, as the material is five-fourths stronger in tension than in shearing, a rivet in single shear is more than one-half as strong as it is in double shear.

A riveted seam is an element of weakness; therefore, an increase of thickness of the shell is necessary in order to compensate for the material cut away by the line of rivets. And, since equation 1 shows that the thickness of the shell to withstand pressure is independent of its length, a girth strip of the shell, equal in length to the pitch of the rivets, will be sufficient for investigating the relation between p, the pitch of the rivets; d, the diameter of the rivets; t, the thickness of the shell plates, and l, the lap of the plates or butt straps, all in inches.

The simplest form of a riveted seam is the single riveted lap joint which is used in marine boilers only where the seam is exposed to the fire. However, to show how it would change the boiler scantling, suppose the boiler to have its longitudinal seams single riveted lap joints. The form and the location of the boiler limit its diameter to 60 inches. The boiler sheets have been tested and found to have the following ultimate strengths:

Ultimate tensile strength $T = 65{,}000$ pounds per square inch.

Ultimate crushing strength $C = 70{,}000$ pounds per square inch.

The rivets are of milder steel than the shell, and have an ultimate tensile strength of 55,000 pounds per square inch, and an ultimate single shearing strength $S = 44{,}000$ pounds per square inch.

Figure 4 shows that in this seam there are $(p - d)\,t$ square inches of the shell in the length of one pitch, and, as each square inch has an ultimate tensile strength of 65,000 pounds, the total stress in pounds necessary to rupture the shell between two adjacent rivets will be

$$65{,}000\,(p - d)\,t \qquad (8)$$

The projected area of the one rivet, on which the stress comes tending to crush the rivet and also the sheet in front of the rivet, is $d \times t$, and as each square inch of the rivet at instant of crushing sustains a stress of 70,000 pounds, the total crushing stress at instant of giving way will be

$$70{,}000 \times d \times t \tag{9}$$

In order that the plate may tear just as the rivet and the sheet in front of it are on the point of crushing, the expressions 8 and 9 must be equal—that is,

$$65{,}000\,(p - d) \times t = 70{,}000 \times d \times t$$

or

$$\frac{p}{d} = \frac{27}{13} \tag{10}$$

In order to get this equation in shape for future use, it is changed by division to

$$p : (p - d) :: 27 : 27 - 13$$

or

$$(p - d) = \frac{14}{27} \times p \tag{11}$$

Making the shearing strength of the rivet equal to the crushing strength of the plate in front of the rivet, gives

$$44{,}000 \times .7854\, d^2 = 70{,}000 \times d \times t$$

or

$$\frac{d}{t} = 2.026 \tag{12}$$

Suppose the working pressure required is 50 pounds per square inch, gauge pressure. Then, to insure safety from rupture along the row of rivets, the following relation of P, r, p, t and d, as given by equation 1, must hold:

$$P \times r \times p = \frac{T}{4.5}\,(p - d) \times t \tag{13}$$

Making substitutions, remembering that from equation 11, $p - d = \frac{14}{27}\,p$, gives, $50 \times 30 \times p = \frac{65{,}000}{4.5} \times \frac{14}{27} \times pt$, from which

$$t = \frac{50 \times 30 \times 4.5 \times 27}{65{,}000 \times 14} = .2003'' = \tfrac{13}{64}''.$$

This value of t in equation 12 gives, $d = 2.026 \times .2003 = .4058'' = \frac{13}{32}''$. And this value of d in equation 10 gives

$$p = \frac{27 \times .4058}{13} = .843'' = \tfrac{27}{32}''.$$

The efficiency of this seam is only 52 per cent. It is needless to say that it would not be used in practice for longitudinal seams for the shell of a boiler to carry any but very low pressures. As already noted, this seam is used for seams exposed to the direct action of the fire.

A double-riveted lap seam is sometimes used for boilers with small diameters, designed to carry moderate pressures.

Experiments show that the ultimate tensile, shearing and crushing strengths increase as the number of rows of rivets increases, due, perhaps, to the prevention of the flow of the material. This explanation is not sufficient to warrant an increase of the coefficients of strength.

This seam is here taken as an illustration of a principle in design, and not as one to be used in large boilers carrying high steam pressures.

Assume a boiler 100 inches in diameter and to carry 85 pounds steam pressure. Then proceeding in a manner similar to that employed for the single-riveted lap seam, noting, of course, that there are now two rivets to take the shearing and crushing stresses, while the section of the shell in tension is as before, $(p-d)\,t$, t, d and p can be found for the double riveted seam.

Referring to figure 5, and equating the tensile and crushing strengths, gives

$$65{,}000\,(p-d)\,t = 70{,}000 \times 2dt$$

or

$$\frac{p}{d} = \frac{41}{13} \tag{14}$$

By division,

$$p : (p-d) :: 41 : (41-13)$$

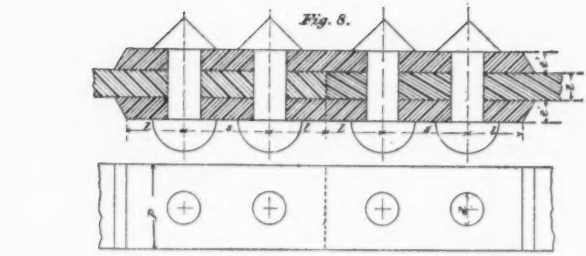
and

$$(p-d) = \frac{28 \times p}{41} \tag{15}$$

The equality of the shearing and crushing strengths for a double riveted seam gives, $44{,}000 \times 2 \times .7854 \times d^2 = 70{,}000 \times 2dt$, from which the ratio

$$\frac{d}{t} = 2.026 \tag{16}$$

Fig. 8.



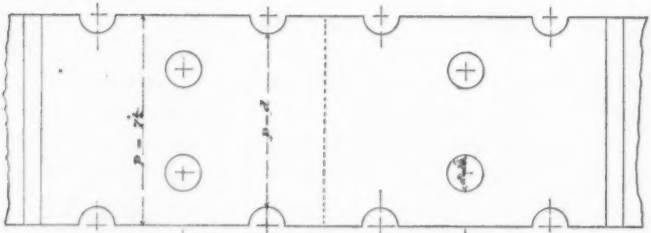
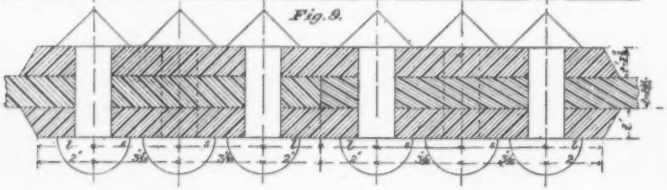


Fig. 9.



Making the stress of the working pressure equal to the safe allowable stress in the material of the seams, gives

$$85 \times 50 \times p = \frac{65{,}000}{4.5}(p - d)\,t \qquad (17)$$

Substituting the value of $(p - d)$ from equation 15, gives

$$85 \times 50 \times p = \frac{65{,}000}{4.5} \times \frac{28}{41} p \times t$$

or

$$t = \frac{85 \times 50 \times 4.5 \times 41}{65{,}000 \times 28} = .432'' = \tfrac{7}{16}''.$$

From equation 16, $\frac{d}{t} = 2.026$. The value of t introduced in this equation, gives $d = 2.026 \times .432 = .875'' = \frac{7}{8}''$.

Equation 14 gives $p = \frac{41}{13} \times .875 = 2.76'' = 2\frac{3}{4}''$.

This seam has an efficiency of 68 per cent. for shearing, crushing and tensile strengths.

The specifications for inspection of steel for boiler rivets used in the U. S. Navy require that "the rivets for use in the longitudinal seams of boiler shells shall have from 58,000 to 67,000 pounds tensile strength, with an elongation of not less than 26 per cent. in 8 inches; and all others shall have a tensile strength from 50,000 to 58,000 pounds, with an elongation not less than 30 per cent. in 8 inches."

Four-fifths of the mean tensile strength of rivets indicates that it is advisable to use 44,000 pounds, instead of 52,000 pounds, per square inch as the ultimate shearing strength of the rivets. Better proportions for riveted seams are obtained, in working out the design for a boiler to carry high pressure, when the shearing strength is taken at 44,000 pounds.

In considering the double riveted seam with double butt straps, it will be seen in figure 8 that the stress will tend to shear each rivet in two places. The other conditions remain the same as in the double riveted lap seam.

The equality of the tensile and crushing strengths gives

$$65{,}000\,(p - d)\,t = 70{,}000 \times 2dt, \text{ or } \frac{p}{d} = \frac{41}{13} = 3.15 \qquad (18)$$

By division, $p : (p - d) :: 41 : 28$

or
$$(p - d) = \frac{28\,p}{41} \tag{19}$$

Equating the shearing and the crushing strengths of the rivets, remembering that there are two rivets each under a double shearing stress, and that a rivet under such conditions has $1\frac{3}{4}$ times the strength as the same rivet under single shear, gives $44{,}000 \times 2 \times 1\frac{3}{4} \times .7854d^2 = 70{,}000 \times 2dt$, from which the ratio,

$$\frac{d}{t} = 1.158 \tag{20}$$

This seam is for a boiler designed to carry a working pressure of 120 pounds per gauge, and the available space limits its diameter to 10 feet. Making the stress of the working pressure equal to the safe allowable tensile strength of one pitch length, gives $120 \times 60 \times p = \frac{65{,}000}{4.5}(p - d)\,t$, from which, by substituting the value of $(p - d)$ from equation 19, is obtained

$$t = .728'' = \tfrac{23}{32}'' \tag{21}$$

This value of t in equation 20, gives $d = 1.158 \times .728 = .843''$ $= \frac{27''}{32}$, and this value of d in equation 18, gives $p = 3.15 \times .843$ $= 2.655'' = 2\frac{21}{32}''$.

Let the foregoing principles be applied to the design of the longitudinal seams for the boilers of the *Cincinnati* and *Raleigh*. The diameter of these boilers $= 14'\,6'' = 174''$; working pressure, 160 pounds per square inch per gauge. The seam to be triple riveted with alternate rivets omitted, as shown in figure 9. The seam is to have double butt straps, as shown in the sketch. Factor of safety, 4.5. The pitch is taken between centers of adjacent rivets in the rows with alternate ones missing, because along these rows there exists the greatest tendency to rupture.

Equating the tensile and crushing strengths of the shell material, observing that there are the equivalents of four rivets to take the crushing stress, gives $65{,}000\,(p - d)\,t = 70{,}000 \times 4dt$, from which

$$\frac{p}{d} = \frac{69}{13} \tag{22}$$

And from this equation by division,

$$(p - d) = \frac{56p}{69} \tag{23}$$

The equality of the shearing and crushing strengths, allowing the rivets in double shear $1\frac{3}{4}$ times their value in single shear, gives $44{,}000 \times 4 \times 1\frac{3}{4} \times .7854d^2 = 70{,}000 \times 4dt$, from which the ratio of d to t is found to be

$$\frac{d}{t} = 1.158 \tag{24}$$

Making the stress produced by the working pressure equal to the safe tensile strength of a ring of the shell one pitch in length, gives

$$160 \times 87 \times p = \frac{65{,}000}{4.5}(p - d)\,t.$$

Introducing the value of $(p - d)$ from equation 23 and reducing, gives

$$t = 1.187'' = 1\tfrac{3}{16}''.$$

This value of t in equation 24 gives

$$d = 1.158 \times 1.187 = 1.375'' = 1\tfrac{3}{8}''.$$

And this value of d in equation 22 gives

$$p = \frac{69}{13} \times 1.375 = 7.3'' = 7\tfrac{5}{16}''.$$

The boilers as built for these vessels had the following corresponding particulars:

$$t = 1\tfrac{15}{64}''.$$
$$d = 1\tfrac{5}{16}''.$$
$$p = 7\tfrac{1}{2}''.$$

An extra $\frac{1}{16}$ inch in the thickness of the shell should be made to allow for corrosion. The rivets encased in the rivet holes are well protected, and need no allowance for corrosion. The working pressure can be kept constant until more than $\frac{1}{16}$ inch has corroded away. After this, the working pressure must be reduced as the shell becomes weaker.

An inspection of figure 7, which is a reproduction of a photograph of a tested seam made at the Watertown Arsenal by the Ordnance Department, U. S. Army, shows that the lap of the seam and the pitch and diameter of the rivets were well pro-

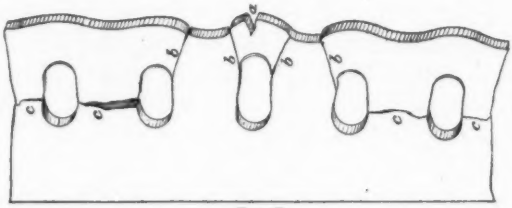


FIG. 7.

portioned for maximum strength. It further shows at a that the portion of the plate in front of the middle rivet began to fail as a beam fixed at the ends and uniformly loaded. Treating the lap in this way, taking

Length of the beam $= d$, the diameter of the rivet.

Breadth of the beam $= t$, the thickness of the plate.

Depth of the beam $= \frac{2l - d}{2}$. The lap l is the distance from the center of the rivet hole to the edge of the plate. This includes the amount for strength plus a small allowance for chipping and caulking.

The safe load for a beam fixed at both ends and uniformly loaded, or more properly loaded at the middle, as the load is applied over the cylindrical surface of the rivet, can be found by the formula

$$\frac{T \times I}{4.5 \times e} = \frac{W \times d}{8} \qquad (25)$$

$T = 65{,}000$ pounds, tensile strength per square inch of the plate.

$I = \frac{1}{12} \times \left(\frac{2l - d}{2}\right)^3 t$, gravity moment of inertia of the section of the beam.

$e = \frac{1}{2}\left(\frac{2l - d}{2}\right)$, distance of outer fiber from the neutral axis.

$W = (p - d)\,t \times \dfrac{T}{4{\cdot}5}$ for single riveting.

d = length of beam = diameter of rivet.

Adapting this formula to the case of the triple riveted seam, such as used in the boilers of the *Cincinnati* and the *Raleigh*, the stress will be divided between *four* rivets in one pitch. In this case then the safe load

$$W = \frac{(p - d)\,t}{4} \times \frac{65{,}000}{4{\cdot}5} \tag{26}$$

These values substituted in formula 25 give

$$\frac{65{,}000 \times \frac{1}{12} \times t \times \left(\frac{2l - d}{2}\right)^3}{4{\cdot}5 \times \frac{1}{2}\left(\frac{2l - d}{2}\right)} = \frac{(p - d)\,t \times 65{,}000 \times d}{8 \times 4 \times 4{\cdot}5} \tag{27}$$

Solving for the lap,

$$l = \frac{d}{2} + \sqrt{\tfrac{3}{16}(p - d)\,d} \tag{28}$$

Introducing the values of p and d for the longitudinal seams of the boilers for the *Cincinnati* and *Raleigh*, equation 28 gives, for the lap,

$$l = 1{\cdot}928'' = 1\tfrac{15}{16}''.$$

Of the numerous results examined where the seams failed through the lap, many have finally given way by shearing out the portion of the plate in front of the rivet. This accords with what ought to be expected from the relative shearing and tensile strengths of steel plates. Where the lap had an excess of strength, the tested seams failed by tearing the plates between the rivets or by shearing the rivets.

Had equation 28 been adapted to the case of a double riveted seam with double butt straps, it would have taken the form

$$l = \sqrt{\tfrac{3}{8}(p - d)\,d} + \frac{d}{2} \tag{29}$$

The breaks b, b, b, b, in figure 7, suggest another manner of

proportioning the lap for riveted seams. If the shearing strength of the plate in front of the rivet be made equal in strength to the other parts already considered, the seam will have a maximum strength with the minimum amount of material.

Making the crushing strength of the rivet equal to the shearing strength of the plate in front of it, gives

$$(2l - d)\, t \times S = dt \times C \qquad (30)$$

Making substitutions for the shearing and the crushing strengths, S and C, and reducing,

$$(2l - d)\, 44{,}000 = d \times 70{,}000$$

and

$$l = 1.3d$$

Making an allowance of $\frac{3}{16}''$ for chipping and caulking, gives the total lap

$$l = 1.5d \qquad (31)$$

Applying formula 31 to the lap of the seams of the boilers for the *Cincinnati* and *Raleigh*, gives $l = 1\frac{5}{16} \times 1.3 = 1\ 97''$. As constructed, the seams of these boilers were given $2''$ lap.

For strength alone, the thickness of each of the butt straps should be equal to one-half the thickness of the shell sheet. But to resist deflection of the butt straps between the rivets, to prevent leakage, it is necessary to increase them to three-fourths of or to the thickness of the shell sheet.

The distance between the rows in zig zag or staggered riveting ought to be enough so that the plate will not tear in a zig zag direction between the rivets. The stress in the plate has a shearing component, consequently the plate requires more sec tion to resist this than if the stress were tensile only.

In figure 10, page 281, p represents the pitch in the horizontal rows, while p' represents the pitch in a zig zag direction. Resolving the safe allowable stress in one-half the horizontal pitch along the plane AB, and making it equal to the safe shearing stress along the same plane, gives

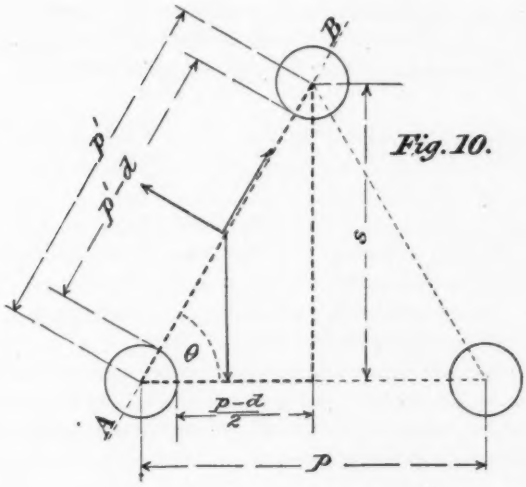


Fig. 10.

$$\frac{T}{4{\cdot}5}\left(\frac{p-d}{2}\right) t \sin\theta = \frac{S}{4{\cdot}5}(p'-d)\,t$$

or
$$\frac{(p'-d)}{(p-d)} = \frac{T}{2S}\sin\theta \qquad (32)$$

Resolving this safe allowable stress at right angles to the plane AB, gives

$$\frac{T}{4{\cdot}5} \times \frac{(p-d)}{2} \times t \times \cos\theta = \frac{T}{4{\cdot}5} \times (p-d)\,t$$

or
$$\frac{(p'-d)}{(p-d)} = \frac{\cos\theta}{2} \qquad (33)$$

The first terms of equations 32 and 33 are identical, therefore,

$$\frac{T}{2S}\sin\theta = \frac{\cos\theta}{2} \qquad (34)$$

The shearing strength of steel plates is four-fifths of its tensile strength, or $S = \frac{4}{5}T$.

This value of S in equation 34 gives $\dfrac{\sin\theta}{\cos\theta} = \tan\theta = .8$, from which $\theta = 38° 40'$.

In laying out the rivet holes, it will be more convenient to have the distance s between the rows of rivets given in terms of the pitch. Referring to figure 10, it will be seen that

$$\tan \theta = s \div \frac{p}{2} = \frac{2s}{p} = .8$$

or

$$s = .4p \tag{35}$$

The disposition of the material in the flat surfaces of a boiler is such that no advantage can be taken of its strength to resist pressure, as is done when the material is worked into cylindrical shapes. It then becomes necessary to support the flat surfaces of a boiler by stay bolts and braces.

If the pitch of the stay bolts or braces be represented by l, then the area supported by each stay or brace will be equal to l^2. If P equal the pressure per square inch on the flat surface, then the total pressure supported by each stay or bolt will equal

$$P \times l^2 \tag{36}$$

The safe load per square inch of section of good steel stays and braces is 8,000 pounds, therefore, the area of each stay must be such that

$$8{,}000 \times \frac{\pi d^2}{4} = P \times l \tag{37}$$

or

$$d = \sqrt{\frac{P \times l^2}{6{,}823}} \tag{38}$$

This diameter, d, of the braces and stay bolts, is taken at the root of the threads where the ends are fitted with nuts.

The pitch, l, of the stay bolts and braces depends, in a measure, on the thickness of the flat plates supported, as will appear by treating the square as a beam supported at the ends and uniformly loaded, in which case from Church's Mechanics, p. 331, equation 4,

$$\frac{R' \times I}{e} = \frac{W \times l}{12} \tag{39}$$

$R' = \frac{65{,}000}{4.5}$. $I = \frac{l \times t^3}{12}$. $e = \frac{t}{2}$. $W = P \times l^2$. $l =$ pitch

of braces or stay bolts. Making these substitutions in equation 39 and reducing,

$$l = \sqrt{\frac{28{,}900 \times t^2}{P}} \quad . \qquad (40)$$

The fire surfaces of the boilers are limited in thickness from $\frac{1}{2}''$ to $\frac{5}{8}''$, and these thicknesses introduced into formula 40 give for the pitch, l, of the back connection stay bolts, $6\frac{1}{2}''$ to $8\frac{3}{8}''$.

To facilitate cleaning the inside of the boilers, the braces are spaced so that a man can pass between them. The flat plates are strengthened by stiffening strips, or else by large washers riveted to the plates through which the ends of the braces extend. Knowing the pitch of the braces and the pressure to be carried in the boiler, the equivalent thickness of the flat sheets to be supported can be ascertained by substituting these values in equation 40 and solving for t.

The value of l from formula 40, substituted in formula 38, will give the necessary diameter for the stays and braces.

A comparison with the results given in the Report on Experiments in Boiler Bracing by the Bureau of Steam Engineering in 1879, shows that the method given above, for pitching stays and braces for flat surfaces, produces results within the percentage of variation in the quality of material and workmanship.

The top of the combustion chamber is supported by stay bolts suspended from girders which span the flat surface. The spacing and size of these bolts have already been determined by formulæ 38 and 40. There yet remains to be determined the size of the girders which support the flat top of the combustion chamber against collapsing. Formula 1, page 270 of Church's Mechanics, gives, for a beam supported at the ends and loaded similarly to a back connection girder, carrying three stay bolts,

$$\frac{R' \times I}{e} = P_0 l_2 - P_1 (l_2 - l_1) \qquad (41)$$

$R' = 8{,}500$ pounds, safe stress in outer fiber of the girder.

I = gravity moment of inertia of the section of the girder where the greatest moment occurs $= \frac{1}{12} \times bd^3$.

$e = \frac{d}{2}$ = distance of outer fiber from the neutral axis.

P_0 = load at one end of the girder.

P_1 = load on one girder stay bolt.

l_1 = one pitch of girder stay bolt.

l_2 = two pitches of girder stay bolts.

b = breadth of the girder = 1.6 inches.

d = depth of the girder.

The application of formula 40 is shown in the following example of a boiler designed to carry a pressure of 160 pounds per square inch.

Depth of back connection = 24″ = length of girder.

Each girder supports three stay bolts pitched 6 inches.

Each girder will also support a strip of the top of the connection 6 inches wide by 24 inches long, or 144 square inches.

The total load supported by each girder will be, therefore, $144 \times 160 = 23{,}040$ pounds.

$P_0 = 23{,}040 \div 2 = 11{,}520$ pounds. $P_1 = 23{,}040 \div 3 = 7{,}680$ pounds.

$l_1 = 6$ inches and $l_2 = 12$ inches.

Making substitutions in equation 41 and reducing, gives

$$\frac{8{,}500 \times 2 \times bd^3}{12 \times d} = 11{,}520 \times 12 - 7{,}680(12 - 6) \qquad (42)$$

$$d^2 = 40.7$$

$$d = 6.4'' = 6\tfrac{13}{16} \text{ inches.} \qquad (43)$$

The girders are arranged in pairs and, as the foregoing calculation has been for a pair, each piece will have a breadth of $1.6 \div 2 = .8'' = \frac{13}{16}''$.

TEMPERATURE-ENTROPY DIAGRAMS FOR STEAM AND WATER.

By Assistant Engineer Louis M. Nulton, U. S. Navy.

"In the calorimetric study of an engine, the exchanges of heat taking place between the fluid and the internal walls of the cylinder should be determined. This is especially necessary in steam engines, because these exchanges of heat are known to be the principal causes of the difference between the efficiency of an ideal and of an actual engine. In studying this subject the graphic method is of great use. For instance, the heat supplied to the cylinder being represented by a given area, the latter may be divided into several parts, one of which will represent the heat converted into work on the piston, another the heat given up to the condenser and to the surrounding air, and thus a kind of graphic heat balance is obtained. If the heat not utilized in work be further subdivided into its component parts, or into the loss of heat due to the clearance volume, to throttling, and to the action of the walls, it will be possible to show exactly how the heat supplied to the engine has been expended.

"Two methods may be adopted for these graphic representations of the transformation of steam in a cylinder. In the first, which is generally used, the pressures and volumes are taken as ordinates and abscissæ, the surfaces representing areas of work only. The indicator curve thus obtained gives the work done on the piston; but, to show the movements of heat, they must be converted by calculation into mechanical energy for each portion of the stroke. This method of representation is complicated by the fact that the effect of the heat supplied to a body is not only to modify its pressure and volume, but also its internal energy. Only a part, therefore, of the heat is represented in the diagram of pressures and volumes, except in special cases as, for instance, in the isothermal transformation of a gas.

"The new system furnishes a direct graphic representation of the heat supplied to a body, by taking temperature and entropy as the characteristics of its condition."—"Engineering," January 3, 1896, Vol. LXI.

The above extract furnishes sufficient reasons why an engineer should familiarize himself with the diagram, and the object of this article is to try and explain as simply as possible the principles of the Temperature-Entropy Diagram. The facts presented have been compiled from various sources and an effort has been made to present them in a simple and connected manner.

Peabody defines entropy as being a "property of a body similar to specific volume, specific heat and latent heat of expansion, but most nearly akin to temperature. It depends upon the state of a body and not on its method of change." Another definition is that entropy is the measure of the available energy of a system.

At the start, it is best not to confuse oneself with reconciling the various definitions. For all ordinary purposes it will be sufficient if the following explanation, § 1, of the term entropy be accepted.

§ 1. If a body takes in, or rejects, a quantity of heat, dQ, at the absolute temperature T, the entropy of the body is increased, or decreased, such increase or decrease of entropy being $\frac{dQ}{T}$.

Let entropy be represented by the symbol Φ (called by Rankine the thermodynamic function), then the *change of entropy* consequent upon the addition, or subtraction, of the quantity of heat, dQ, at the absolute temperature T, is expressed thus

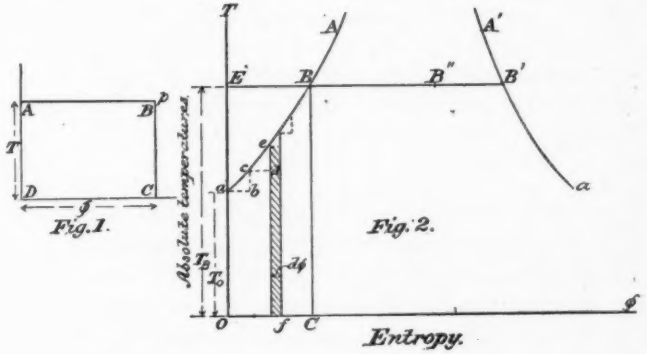
$$d\Phi = d\frac{Q}{T}. \qquad (1)$$

or, with proper limits,

$$\Phi = \frac{Q}{T}. \qquad (2)$$

If we now choose rectangular axes and lay off the values of Φ as abscissæ and the absolute temperatures as ordinates, we can plot the condition of a body as defined by its entropy and absolute temperature.

In Fig. 1, suppose p a point so defined, Φ being the increase of entropy due to the addition of a quantity of heat Q, and T the absolute temperature at which it was added. The area $ABCD =$



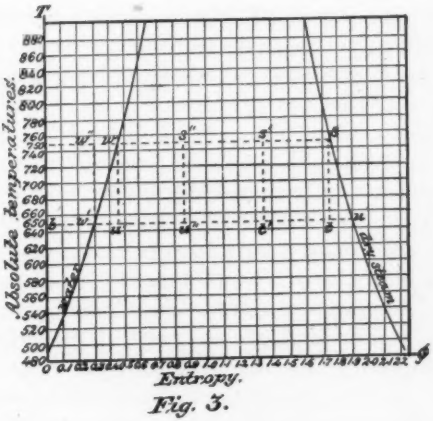


Fig. 3.

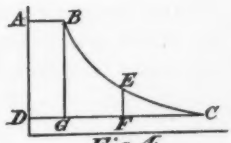


Fig. 4.

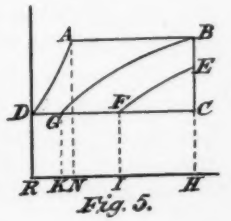


Fig. 5.

$\Phi \times T$, but this, from equation (2), is equal to Q the heat added, and brings us at once to the principle of the Temperature-Entropy Diagram.

It is a thermal diagram representing outflow and inflow of heat in the same manner that the indicator diagrams represent me-

chanical energy exerted on the piston or exerted by the piston. On an indicator diagram an area represents work, on a Temperature-Entropy diagram an area represents a quantity of heat.

In dealing with entropy, as in dealing with total heat, an arbitrary point is chosen, entropy being reckoned from that point as a zero, and the entropy of the substance for every other state will have a value which is perfectly definite and may be calculated. In reckoning entropy, the condition of water at 32° Fahrenheit is taken as the zero.

§2. THE DIAGRAM FOR WATER.

In Fig. 2, let $O\,T$ and $O\,\Phi$ be the axes of absolute temperatures and of entropy.

Let T_o be the absolute temperature corresponding to 32° Fahrenheit, then $\Phi = 0$ at this point, as we have assumed the condition of water at 32° Fahrenheit to be the zero of entropy.

Now, take one pound of water at 32° and add a little heat to it. Then, with reference to our diagram, there are two distinct changes; first, the temperature is raised, and, second, the entropy is increased. In Fig. 2, the increase in entropy is represented by *ab*, and the rise in temperature by *bc*, so that the new condition of the water on the diagram is represented by the point *c*. Now, let a little more heat be added, and the temperature and entropy be still further increased, as by *cd*, and *de*, so that the new condition is now represented by the point *e*. We can at once see that when the additions of heat are infinitely small and continuous, *i. e.*, when heat is added proportional to the rise in temperature, the points representing the condition of the water at each instant will, when plotted on the diagram, lie on a curve *aA*.

Let *B* be a point on the curve whose absolute temperature is T_B. Then the area *OaBC* represents the quantity of heat supplied between the limits of temperature T_o and T_B, and if a is the heat supplied for each degree of rise in temperature, *i. e.*, the mean specific heat of water, then the area $OaBC =$

$a\int_{T_0}^{T_B} dT$. The area of any element, as ef, is $Td\Phi$, and the whole area $OaBC$ is equal also to $\int_0^{\Phi_B} Td\Phi$, and we have

$$\int_0^{\Phi_B} T\,d\Phi = a\int_{T_0}^{T_B} dT$$

or
$$\Phi\Big]_0^{\Phi_B} = a\int_{T_0}^{T_B} \frac{dT}{T} = a\log\varepsilon T\Big]_{T_0}^{T_B}$$

or finally
$$\Phi_B = a\log\varepsilon\frac{T_B}{T_0} \qquad (3)$$

Since the point B may be any point on the curve, and the temperature T_B, the temperature of any such point, we may drop the subscript $_B$ and write for the entropy of water at any temperature

$$\Phi_W = a\ \log\varepsilon\frac{T}{T_0} \qquad (4)$$

where T is the absolute temperature of the water, and T_0 is the absolute temperature of the point taken as the zero of entropy, in this case the absolute temperature corresponding to 32° Fahr.

§ 3. ENTROPY OF STEAM.

Again referring to Fig. 2, suppose that at B the pound of water is completely evaporated, and dry steam formed having the same temperature as the water from which it was formed. Noting the opening sentences of § 1, we at once see that

$$\text{Increase of entropy from } B = \frac{\text{Heat added}}{\text{Absolute temp. at which added}} \qquad (5)$$

The change is an isothermal one, as the temperature has not varied and the increase of entropy, BB', is laid off from B on the horizontal line corresponding to the absolute temperature of B, and the distance of B' from the axis of OT measures the value of the entropy of one pound of dry steam at the absolute temperature T_B. Referring to equation (5), the heat added is the latent heat of steam at the absolute temperature T_B, and calling this L_B, we have from (5)

$$BB' = \frac{L_B}{T_B} \tag{6}$$

$$EB' = EB + BB' = \Phi_B + \frac{L_B}{T_B} = a \log \varepsilon \frac{T_B}{T_o} + \frac{L_B}{T_B}$$

or,
$$\Phi_B' = a \log \varepsilon \frac{T_B}{T_o} + \frac{L_B}{T_B} \tag{7}$$

Again dropping the subscripts, as B is any point, we have for dry steam at any absolute temperature T,

$$\Phi_S = a \log \frac{T}{T_o} + \frac{L}{T} \tag{8}$$

where L is the latent heat corresponding to that temperature, and a is the mean specific heat of water at that temperature, T_o being, as before, the absolute temperature of the zero of entropy. Plotting the curve as given by equation (8), we get $A'a'$, Fig. 2. Comparing equations (8) and (4), we see that the entropy curve for dry steam is formed by laying off, from each point on the curve for water, the value of $\frac{L}{T}$, and, since the latent heat of steam decreases as the temperature rises, the value of $\frac{L}{T}$ will decrease as we ascend the scale of temperature and the curves will approach each other.

§ 4. FIXTURE OF WATER AND STEAM.

Again referring to the condition of the water at the point B, Fig. 2, suppose that only a fraction, x_B, is evaporated. We would have a mixture of steam and water, and the heat added at the point B would be only $x_B L_B$, and the increase of entropy would be BB'', less than BB'.

By equation (5)

$$BB'' = \frac{x_B L_B}{T_B} \tag{9}$$

and
$$\Phi_B'' = a \log \varepsilon \frac{T_B}{T_o} + \frac{x_B L_B}{T_B}$$

or dropping the subscripts,

$$\Phi = a \log \varepsilon \frac{T}{T_o} + \frac{xL}{T} \tag{10}$$

It is evident that equation (10) is the general equation, for if we make $x = 0$, we get equation (4), and if we make $x = 1$, we have equation (8), and any mixture between the limits of all water and all dry steam can be represented in (10) by giving the proper value to x, which is the *dryness fraction.*

The completed diagram is shown in Fig. 3. The base line, $O\Phi$, in Fig. 2, from which absolute temperatures are measured, is left out in Fig. 3, as being unnecessary after the diagram is completed.

§4. ISOTHERMAL LINES ON THE DIAGRAM.

Isothermal changes are at constant temperature, so at once the change of entropy, consequent upon an isothermal change, is a straight line parallel to the axes $O\Phi$, from which absolute temperatures are measured.

§6. ADIABATIC LINES ON THE DIAGRAM.

Again referring to the opening lines of § 1, we see that a body changes its entropy when it takes in or rejects heat. In an adiabatic change heat is neither gained nor lost, consequently there is no change in the value of the entropy.

If steam expand adiabatically, doing work in a non-conducting cylinder, it neither gains nor loses heat, but the temperature falls. The value of its entropy is the same after expansion as before, as there is no change in heat, and the expansion line on the diagram of temperature and entropy will be a straight line parallel to the axis of absolute temperature.

For example: one pound of saturated steam at an absolute temperature of 750° expands as above until its temperature falls to 650°. The intersection of the temperature line for 750°, Fig. 3, with the curve for steam, gives the point s as representing the initial condition of the steam on the diagram, and st, parallel to OT, represents the adiabatic expansion.

§7. DRYNESS FRACTION.

The horizontal distance between the water and steam curves at any point is equal to $\frac{L}{T}$ for that temperature. If the steam re-

ferred to immediately above had contained a certain per centum of moisture, the point representing it would be s', where $ws' = \frac{xL}{T}$, x being the dryness fraction, L the latent heat, and T the absolute temperature corresponding to the point s', the absolute temperature being 750° in the case under consideration.

Now $$ws = \frac{L}{T}, \text{ and } ws' = \frac{xL}{T}$$

and $$\frac{ws'}{ws} = \frac{\frac{xL}{T}}{\frac{L}{T}} = x,$$

the dryness fraction of the steam at the point s'.

From this we see that if steam in a certain condition is represented by a point on the diagram, its dryness is given by the following equation:

Dryness fraction at any point

$$= \frac{\text{Distance of this point from the water curve}}{\text{Distance between the curves}} \qquad (11)$$

these distances being measured on the temperature line through the point.

§ 8. ADIABATIC EXPANSION OF { I. DRY STEAM. II. WATER. III. MIXTURES OF STEAM AND WATER

Case I.—If dry steam expand adiabatically, doing work in a non-conducting cylinder, steam is condensed during expansion.

For example: let the steam be initially dry at the absolute temperature of 750°, and let it expand until its temperature falls to 650° absolute. Then on Fig. 3, s is the point representing the initial condition, st the expansion line, and t the point representing the condition of the steam after expansion. At s we have, from equation (11), dryness fraction $= \frac{ws}{ws} = 1$. Similarly, at t we have dryness fraction $= \frac{w't}{w'u} =$ less than unity. Hence, during the expansion, the dryness fraction has been decreased

from unity to less than unity, showing that there is less dry steam at the end of the expansion than there was at the beginning, *i. e.*, steam has been condensed during the expansion.

Case II. Water.—Suppose a pound of water, under a pressure of P pounds per square inch, has put into it enough heat to raise its temperature to the boiling point for P, but none is evaporated. Now suppose the water while in this condition has the pressure reduced from P to p pounds per square inch, and the temperature is allowed to fall to that of the boiling point for p, and during the operation the water is not to gain any heat or lose any, but may adjust itself by any change in volume to suit the final pressure and temperature. By the adiabatic expansion of water is meant the above process, and we see, by again referring to the opening words of § 1, that the entropy is constant during this change and is represented on the diagram by a straight line parallel to the axis of absolute temperatures.

If water expand adiabatically, some of it is evaporated.

Let w be the point on the water curve corresponding to the absolute temperature of the boiling point for P above, and let the water expand adiabatically to u', where u' is on the temperature line corresponding to the absolute temperature for the boiling point for p.

At w we have, from equation (11), $x = \frac{0}{ws} = 0$, and naturally so since we started with all water and no steam.

Similarly at u', we have $x = \frac{w'u'}{w'u} =$ a finite quantity.

Hence, in the above expansion, the dryness fraction has increased from 0 to some definite value, showing that there is some steam present, *i. e.*, water has been evaporated.

Case III. Mixture of Water and Steam.—If a mixture of water and steam expand adiabatically, there are two cases to consider; (1) where there is more steam than water, and (2), where there is more water than steam.

Let us start from s' for case (1) and from s'', Fig. 3, for case (2), both expansions to be between the limits of 750° and 650°.

Using the units of the scale of the base line, we have at s', $x = \frac{ws'}{ws} = \frac{0.9}{1.3} = 68.1$ per cent.

After expansion, we have at t', $x = \frac{t'w'}{w'u} = \frac{1.05}{1.56} = 67.1$ per cent, showing that there is $68.1 - 67.1 = 1$ per cent *less* dry steam after expansion than there was before.

Similarly at s'', for case (2), $x = \frac{ws''}{ws} = \frac{0.4}{1.3} = 30.8$ per cent.

After expansion, we have at u'', $x = \frac{w'u''}{w'u} = \frac{0.575}{1.56} = 36.9$ per cent, showing that there is $36.9 - 30.8 = 6.1$ per cent *more* dry steam after expansion than before.

From the above examples we see that, *if there is more steam than water* in the mixture, *steam is condensed during expansion*, but *if there is more water than steam, steam is formed during the expansion.* This general statement can be proved by taking points to represent various values of x and then making the calculations as above. From what has been said, it might be supposed that if a mixture half steam and half water expand adiabatically, *i. e.*, $x = 0.5$, the condensation and evaporation during the expansion would be equal and the dryness be the same after expansion as before. This will not be so, although very nearly so, because the ratio $\frac{L}{T}$, the distance between the curves at any point, is not a constant ratio, but varies slightly at different temperatures.

§9. DEDUCTION OF THE ADIABATIC EQUATION FROM THE DIAGRAM.

Let steam expand adiabatically from the absolute temperature T_1 to the absolute temperature T_2, as from s' to t', Fig. 3. The value of the entropy has not changed during the expansion, but is the same after as before, so that we have

$$bt' = as'$$

or

$$bw' + w't' = aw + ws'$$

and substituting the values of these as given by equations (4) and (9), we have

$$a \log \varepsilon \frac{T_2}{T_o} + \frac{x_2 L_2}{T_2} = a \log \varepsilon \frac{T_1}{T_o} + \frac{x_1 L_1}{T_1}$$

or
$$\frac{x_2 L_2}{T_2} = a \log \varepsilon \frac{T_1}{T_o} - a \log \varepsilon \frac{T_2}{T_o} + \frac{x_1 L_1}{T_1}$$

$$= a \log \varepsilon \frac{\frac{T_1}{T_o}}{\frac{T_2}{T_o}} + \frac{x_1 L_1}{T_1}$$

finally we have
$$\frac{x_2 L_2}{T_2} = a \log \varepsilon \frac{T_1}{T_2} + \frac{x_1 L_1}{T_1} \qquad (12)$$

which is the equation for steam expanding adiabatically and doing work in a non-conducting cylinder. The specific heat of water a is nearly always taken as unity.

§ 10. PLOTTING THE ORDINARY INDICATOR DIAGRAM ON THE TEMPERATURE-ENTROPY DIAGRAM.

Under this head there are three cases to consider, (1) where there is *complete expansion* down to the pressure and temperature of the condenser, (2) where the *steam is used non-expansively*, (3) where the *expansion is incomplete*.

In Fig. 4, let (1) *ABCD*, (2) *ABGD*, and (3) *ABEFD* be ideal indicator cards from one pound of steam used as in cases (1), (2), and (3) above, the temperature of feed being 32° Fahrenheit in each case. In each case *DA*, Fig. 4, represents the rise in pressure as the feed water enters the boiler, and also for the case under consideration, the rise in temperature as the feed is heated to the boiling point, and on the entropy diagram, *DA* would be plotted as shown in Fig. 5,* while the quantity of heat received by the water is represented by the area *RDAN*. (See § 2.)

Also in each case, *AB*, Fig. 4, represents the increase in volume as the one pound of water is evaporated into dry steam. This is an isothermal change, from water at one temperature to steam at the same temperature, shown on the entropy diagram by *AB*, Fig. 5, and the additional heat received during the conversion to steam is represented by the area *ABHN*.

* Corresponding lines have the same lettering in Figs. 4 and 5.

So far the entropy diagram has been the same for each of the three cases, and naturally so, since in each case we raise one pound of water from the same temperature of the feed and evaporate it at the same pressure, or temperature. After this point, the cards differ on the entropy diagram, and the cases will be considered separately.

Case (1). *Complete Expansion.*—From *B* to *C*, Fig. 4, the steam expands adiabatically, and this change is plotted as *BC* of Fig. 5. From *C* to *D* in Fig. 4, the steam is all swept out of the cylinder and changed to water of the same temperature. This is an isothermal change, and is shown as *CD* of Fig. 5, the heat rejected to the condenser being represented by the area *CDRH*. We have now for case 1 on the entropy diagram, Fig. 5,

Heat expended to raise feed water to boiling point = area *DANR*
Heat received during evaporation = area *ABHN*
Total heat received = area *RDABH*
Heat rejected = area *RDCH*
Heat utilized = area *DABC*.

corresponding to the work area *DABC* of Fig. 4.

Case (2). *No Expansion.*—The indicator card for this is *ABGD*, Fig. 4. When the piston is at *B*, the cylinder is opened to the condenser, the temperature of the cylinder falls to that of the condenser before the piston has moved, and the steam gives up heat as the temperature falls. This is plotted on the entropy diagram of Fig. 5, by the curve *GB*, a curve similar to *aA*, Fig. 3, (see §2,) but reversed.

After the temperature has fallen to that of the condenser, the piston moves from *G* to *D* and sweeps the contents of the cylinder into the condenser, and we have the isothermal *GD*, Figs. 4 and 5.

As in case (1),

Heat received = area *RDAN* + area *NABH*. . . Fig. 5.
Heat rejected = area *BGKH* + area *RDGK*.
Heat utilized = area *ABGD*,

corresponding to the work area *ABGD*, of Fig. 4.

Case (3). *Incomplete Expansion.*—This case evidently lies between the above cases, and is plotted as *ABEFD* in both Figs. 4 and 5.

§ 11. PRACTICAL APPLICATION OF THE FOREGOING PRINCIPLES.

Those who are interested in the practical application of the above principles are referred to an article in "Engineering," of January 3, 1896, on the application of the entropy diagram to the analysis of a compound condensing steam engine, which is too long to be inserted in this paper.

FORCED DRAFT TRIAL OF THE U. S. S. *RALEIGH.*

By Chief Engineer C. R. Roelker, U. S. Navy.

On March 25, 1896, the U. S. S. *Raleigh* went to sea from Hampton Roads, Va., for a forced draft, full power trial. The vessel had recently been docked at Norfolk, Va., and her bottom thoroughly cleaned and painted. The vessel was in her ordinary cruising condition, with all her weights on board and all the boats in the cradles or on the davits. The bunkers had been filled with New River steam coal, run of the mine, containing about 45 per cent. of lump and 55 per cent. of slack. The draught of the vessel was 19 feet 1 inch forward and 19 feet 11 inches aft, corresponding to a displacement of 3,574 tons of sea water.

Only the regular crew of the vessel was employed during this trial. In addition to the regular engineer's force, consisting, exclusive of mess cooks, of 86 men available for duty in engine and fire rooms and coal bunkers, 12 men of the deck force were detailed to assist in trimming coal in the upper bunkers. As this was the first time, since the *Raleigh* had gone into commission nearly two years ago, that the forced draft system with closed fire rooms was tried in this vessel, many of the firemen had no experience or training in firing under these conditions. Many of the oilers likewise had little experience with high speed engines.

The fire room and bunker force was divided into two watches, one of which remained on duty until the fire rooms were closed and returned to duty immediately after the trial.

The boilers were clean and filled with fresh water.

Fires were lighted shortly after midnight of March 25th, and at 6·02 A. M. the vessel got under way from her anchorage off Fortress Monroe and stood out to sea.

At 9·30 A. M., the trial commenced with the fire room doors and hatch shutters closed and the forced draft blowers running at an average speed of 530 revolutions per minute. All the fire

rooms were in communication, and the air pressure rose to 1.3 inches of water.

At 10·10 A. M., the blower of No. 3 fire room became disabled by the breaking of a piston rod. As the inlet and outlet ducts of the blowers are not provided with doors or shutters, a temporary canvas covering was applied to the disabled blower to prevent the escape of air from the fire room, but the pressure fell rapidly to nine-tenths inch of water. The efficiency of the six furnaces in No. 3 fire room was greatly impaired by this accident.

The main engines, air pumps and other auxiliaries worked very satisfactorily. There was not the slightest vibration in any part of the engine framing. No water was used externally on any journal, except for forty minutes during the first hour on one crosshead journal, and for fifteen minutes on one main journal as a precautionary measure. Water was carried over at times into the cylinders of the starboard engine, and for this reason its speed was less than that of the port engine.

At 11·40 A. M., the port circulating pump stopped in consequence of a hot crank pin, which was cooled down in a few minutes, but caused the stopping of the port main engine for about seven minutes. On account of this stoppage, the data taken from 11·30 A. M. to meridian have not been used in computing the mean results; but the trial was continued from meridian to 2 P. M., so as to finish it with an unbroken run of two hours. During these last two hours the engines were racing slightly at times.

Indicator cards were taken on the main engines every half hour, and the readings of the revolution counters, steam, vacuum and air pressure gauges, and thermometers were recorded at the same time.

The coal consumed could not be measured during the trial, but was estimated by inspection of bunkers before and after the trial. The coal used was of a good quality, but, on account of its highly bituminous character, not suitable for forced draft in a closed fire room, as became evident especially during the second half of the trial.

The speed of the vessel was measured by a patent (Walker) log,

the readings of which were recorded every fifteen minutes. The easterly winds which had been prevailing for several days previous to the trial had caused the sea to be quite rough; the vessel plunged into it heavily, head on, during the first two hours, taking green seas over the forecastle. The course of the vessel was then changed so as to take the sea abeam. There was a fresh head wind blowing. The depth of water during the first two hours of the trial was from 14 to 17 fathoms, hardly sufficient for obtaining the best results with a vessel having the draught and the speed of the *Raleigh.*

Besides the main engines, the following auxiliary engines were in operation during the trial, viz: Steering and dynamo engines, one (1) flushing pump, two (2) main air pumps, two (2) main circulating pumps, two (2) water service pumps, two (2) main bilge pumps, two (2) auxiliary bilge pumps (occasionally), two (2) auxiliary air and circulating pumps, four (4) main feed pumps, five (5) fire room blowers, and during first forty minutes, one (1) additional fire room blower.

The general results of the trial are as follows:

Time.	Speed, knots	Mean rev. of main engines.	Mean I.H.P. of main and auxiliary engines.	Sea.	Wind, one point on bow.	Mean depth of water, fathoms.
9·30 to 10·30 A. M...	19.2	143.35	7,159	Moderate..	4	14
10·30 to 11·30 A. M..	19.34	138.35	6,718	Long.....	4	17
Merid. to 1 P. M	18.15	132.40	5.749	Rough	3-4	25
1 to 2 P. M.....	17.88	128.78	5,409	Long.....	3-4	20
Mean.....	18.64	135 72	.....	.....	.....	.....

Slip of screws for mean speed and revolutions, 10.23 per cent.

The maximum power developed during the trial by the port main engine, making 152 revolutions per minute, was 4,394.51 I.H.P.

At 2 P. M., the fire rooms were opened and the fire room blowers stopped.

At the close of the trial, the engines were in as efficient con-

dition for its continuance as at the beginning, but the steam pressure in boilers had fallen to 105 pounds per square inch.

The data of the first two hours of the trial give the following results:

Time of trial	March 25th, 1896—9·30 to 11·30 A. M.	
Duration of trial	Two hours.	
Speed, in knots and tenths	19.27	
Direction and force of wind	One point on bow, 4.	
Direction and kind of sea	Ahead, moderate and long.	
	Starboard	*Port.*
Steam pressure in boilers, by gauge, pounds per square inch	134.75	134.75
at engines, by gauge	131.5	125.25
Revolutions per minute	133.7	148
Vacuum in condenser, by gauge, inches of mercury	24.875	25.375
Temperature in fire rooms, degrees Fahrenheit	144	
engine rooms, degrees Fahrenheit	82	
injection water, degrees Fahrenheit	47.25	
discharge water, degrees Fahrenheit	114	
feed water, degrees Fahrenheit	129.25	
Air pumps, revolutions per minute	128.2	144 5
Circulating pumps, revolutions per minute	91.2	103
Feed pumps, revolutions per minute	35.1	
Main bilge pumps, revolutions per minute	126	
Water service pumps, revolutions per minute	71	
Fire room blowers, revolutions per minute	512	
Air pressure, in inches of water	.96	
INDICATED HORSE POWER.		
Main engines, H.P. cylinder	979.5	1,325.2
I.P. cylinder	949.1	1,274.8
L.P. cylinders, both	926.4	1,258.5
Total	6,713.5	
Air pumps	22.5	28
Circulating pumps	7.3	8.2
Total air and circulating pumps	66.	
Total of all other auxiliary machinery in operation during trial, estimated	159.	
Collective, of main and all auxiliary engines in operation during trial	6,938.5	
Collective, all machinery, per square foot of grate surface, per hour	11.25	
Collective, all machinery, per square foot of heating surface, per hour	.3438	
Coal, per hour, pounds	13,980.	
Coal, per I.H.P. of all machinery, per hour	2.015	
Coal, per square foot of grate surface, per hour	22 66	
Coal, per square foot of heating surface, per hour	.6928	

It will be of interest to compare the speed curve of the *Raleigh*, determined by actual trial, with the curve computed by Passed Assistant Engineer C. A. Carr, U. S. N., published in volume III, No. 4, of this JOURNAL. In the annexed curve, the points plotted represent the indicated horse powers of the main engines only. Points *h*, *i*, *j*, were determined from results of trial on March 25th. Point *g* was obtained January 27, 1896, while steaming with all the boilers in use with open fire rooms and natural draft only during two hours in a smooth sea. The other points were obtained at different periods of the cruise while steaming in smooth water with a clean bottom. The speed was measured in every case by a patent log.

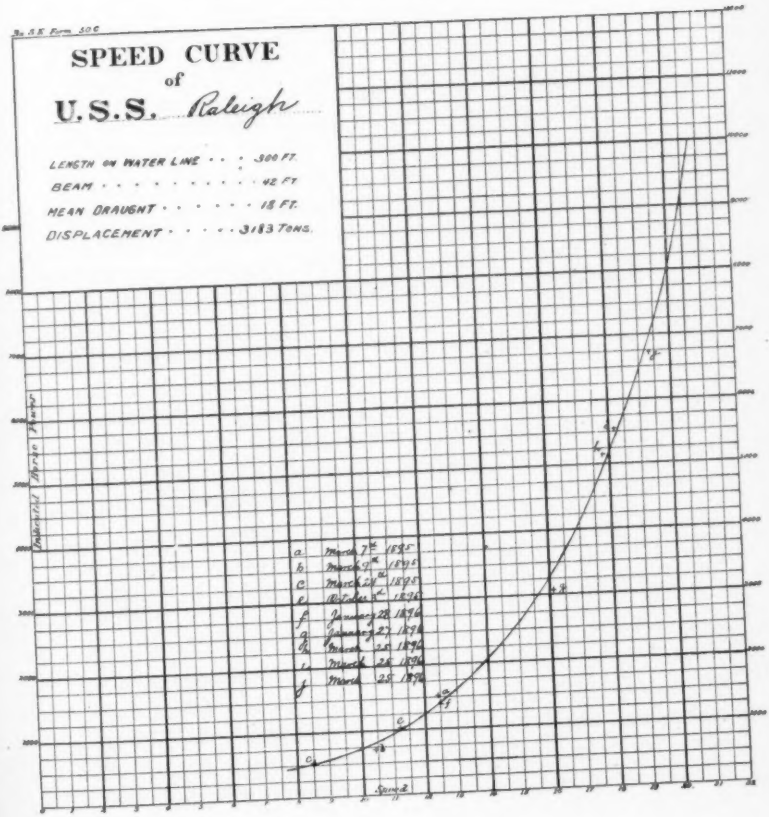
As an approximate measure of the economic performance of the engines of the *Raleigh* at different powers and speeds, the following table is given, showing the weight of steam in cylinders of main engines per indicated horse power per hour, computed from indicator cards. In each case, the mean result obtained from two or more sets of cards is given; but the individual cards gave remarkably uniform results. While the actual amount of steam which entered the engines, and that part which was condensed in the cylinders and not accounted for by the indicators, could not be determined, it may be safely assumed that this amount was proportionately greater at the lower than at the higher engine speeds:

Revolutions of main engines per minute.	*Pounds of steam per I.H.P. per hour computed from indicator cards.*
68.25	26.58
73.	23.17
81.	22.52
83.5	21.82
108.2	17.33
146.75	18.49

No. 5.E. Form 506

SPEED CURVE
of
U.S.S. Raleigh

LENGTH ON WATER LINE . . . 300 FT.
BEAM . . . . . 42 FT.
MEAN DRAUGHT . . . . . 18 FT.
DISPLACEMENT . . . . . 3183 TONS.



a. March 7th 1895
b. March 9th 1895
c. March 24th 1895
d. Raleigh 6th 1896
e. January 28, 1896
f. January 27, 1896
g. March 25, 1896
h. March 25, 1896
i. March 25, 1896
j. March 25, 1896

THE NECESSITY OF ENGINEER DIVISIONS IN THE NAVAL MILITIA.

[Paper read by Alfred Brooks Fry, Lieutenant and Engineer, Massachusetts Naval Brigade, before the Commanding Officers of the Naval Militia of the Atlantic Coast, on board the U. S. S. *New Hampshire*, New York.]

The organization of the Naval Militia of the United States has been attempted and partly carried out on lines which differ widely from the conventional systems of foreign powers establishing a naval reserve, or marine system of coast defense. It is not the purpose of this paper to consider whether our present system is, or is not, best suited to our needs, but, firstly, to attempt to set forth the necessity of a Marine Engineer Force, as part of our Naval Militia system, and, secondly, briefly to sketch a possible method of embodying such a force.

As to the need, it is almost time wasted to point out that, in marine affairs, old things have passed away, all things are become new, and no longer for any military purpose, is sail a factor on board ship. The tophamper of masts and yards has given way to boiler and engine, and topman and after guard of former times must be replaced by the new and varied ratings of the engine and fire rooms.

May I turn aside a moment to say that, so far, those ratings have been rendered heroic more often by actual deeds than by any meed of praise in song or story. Witness Melville as the mainstay of the lost crew of the *Jeannette* in the icy seas of the Arctic, or that fleet engineer of Her Majesty's Navy who, with all the men of his division on duty, lies coffined in the *Victoria*, beneath the blue waters of the Mediterranean, dying with none of the "pomp and circumstance of glorious war," but grimly, midst an Inferno, faithful to the last to their stations, sinking, that their shipmates of the deck might have a chance for life. Nor is it on ships alone that the engineer force has demonstrated

skill and devotion, instance Lieut. Cushing's launch that blew up the Confederate ram *Albemarle*, with half its crew from the engineer division, where the machinist who drove the launch at the ram, literally under the muzzles of her guns, was no less heroic a figure than the gallant officer who set the torpedo.

I trust this digression may be pardoned, made by one who is proud of his trade, for to all of us inspiration may come from every worthy example, nor "is any victory in vain."

Whatever view we may take of the functions of the naval militia, it is apparent that much of its duty must be done afloat, whether that duty be on ships of war, at sea, or coast defense extemporized gun vessels, torpedo launches, or in transport service for land forces. For all these uses, save possibly the last, nothing but steam can be considered. Note, then, the extraordinary condition of the naval militia. Save in two or three organizations, it is practically wholly dependent upon the offices of outsiders in the most vital particular of steam engineering. What would be thought in these times of a body of infantry, which could not make route marches, a cavalry organization that had to employ men to lead the horses of the troopers, or of a battery requiring hired drivers to take the field? To be sure, these conditions existed in part in our ancient militia system, and most dearly in blood and treasure has our country paid for such neglect of the teachings of common sense.

It may be argued that the foregoing illustrations are extreme, and that when the naval militia goes to sea, why, there is the Engineer Corps of the Navy, and if they go in extemporized gunboats, why, the engineers who serve on the boats in civil life can be hired to run them for the militia; so also with steam yachts and launches that may be used for torpedo or vedette purposes.

The theory that the naval militia need furnish no engineer force when on men-of-war has up to the present time worked without difficulty, and, doubtless, if the naval militia were never to serve any other purpose than going nominally to sea, ten days a year, as a sort of hard scrubbing, hard living, good shooting set of passengers, it would continue to work, and no engineer

force, or, for that matter, nothing naval but name would be required. Any body of militia existing on the seaboard, which had received some instructions in the handling of heavy guns, would be just as serviceable on ships as any body of so-called naval militia, the instruction of which has been almost wholly military, and which is rarely drilled in boats or on vessels of any description. On the other hand, it is firmly believed by many qualified officers, that the organization of each separate body of naval militia should approximate a ship's company, large or small; a brigade or large battalion should contain every element necessary to man a coast defense vessel, or a large extemporized cruiser; a small battalion should contain every element necessary to man smaller ships or gunboats, with enough ordnance and steam specialties for vedette or torpedo boats.

For engineers or firemen for duty on extemporized vessels, no naval officers or men can be spared. Of this we are informed by high authority. Capt. Taylor, President of the Naval War College, says in his paper, "The Relation of a Naval Reserve to Coast Defense," in the event of war, "Roughly speaking, therefore, we may say that by a great strain, we could scantily officer, (and man) the regular Fleet." Accepting this statement as conclusive, some may urge that an engineer force could be "hired" from the merchant service. Aye, but are men who are "hired" likely to readily submit themselves to regular discipline? Will those who have nothing but wages at stake, willingly thrust themselves into danger, where they get equal share of the risk, but no part in the credit for success?

Time after time in our late Civil War, did masters, pilots, and engineers, from the merchant service, become officers and a part of the naval and military establishments North and South, rendering gallant and faithful service. Time after time did men from these same classes wisely refuse to subject themselves, as civil employés, to inglorious danger, when money alone was offered as the consideration. We know St. Paul's estimate of the "hireling," and the hirelings of our day are not likely to be more valuable than those of scriptural times.

Moreover, let us not deceive ourselves with the idea that the

engineer or fireman is not as alive to the honor of our country's uniform, as are their shipmates "behind the gun."

Since then, necessity, policy and fairness, make us recognize the need of an engineer division in the Naval Militia, how can it best be formed? The Engineer-in-Chief of the Navy has expressed his opinion that due consideration of local conditions is first necessary; granting this, yet certain general conditions prevail at nearly all large ports on the Atlantic Coast. There are large or small fleets of tugs, some coastwise and some excursion steamers, in nearly every place.

From these vessels not in active commission, and from competent men employed ashore, there can always be enlisted in the naval militia, machinists, oilers, water tenders and firemen, provided some rational inducement is offered, *and they are to be respected as part of the military system.* It may be necessary, in some cases, to compensate them for lost time, for the fact must not be overlooked that the conditions of firemen and engineers who ship in these ratings differ vastly from that of all other men in the militia. The clerk or business man who ships as seaman in the naval militia, finds in his duties afloat a great change from his duties ashore. He gets variety, exercise, fresh air and that relief from monotony of occupation, which medical authorties pronounce the best rest for mind and body. But the man who shifts from the engine room of a merchant ship to that of a man-of-war, gets little change so far as scene and occupation go. The joint that leaks, the bearing that heats and the gauge glass that breaks are the same nuisances everywhere, and the engine room of the man-of-war is the hotter when forced draft and closed stoke holes are used; also, the general comfort of fireman or engineer aboard ship is probably greater in the merchant service, especially on a harbor or coastwise vessel.

The amateur sailorman may readily find that a number of interesting experiments may be tried with guns, large and small, with oars and boats, and even with vessels, provided there is sea room, and the commanding officer keeps in mind article 493, Naval Regulations; on the other hand, it is the experience of most, that marine engines and boilers afford little encouragement

for the display of amateur talent. Therefore, as stated, if under these conditions we ask skilled men to do skilled work for us, it is certainly fair to compensate them for time lost, should their circumstances require it. Also, since in the militia we can offer no pay for profit, it is doubly fair that we see to it that the man who fires, the man who oils, and the man on the platform are recognized as part of the military machine; that they are respected in their ratings, and that the same consideration be accorded them as is accorded their shipmates of the deck.

These conditions have obtained in the organization with which I have the honor to serve. We have been aided and encouraged in every way by officers of the Engineer Corps of the Navy, with whom we have been brought in contact, and we have put afloat an engineer division that has been favorably reported upon, both by the State authorities and by naval boards and officers. It is not, by a good deal, the best organization that can be formed, but, to our mind, it is better than no effort at all in so important a direction. It is fair to state, therefore, that the conclusions of this paper are not drawn from theory alone.

As to the actual form of organization, the writer presents the following brief proposal, which, having the approval of his commanding officer, embodies our idea of an engineer division suitable for a brigade in the Naval Militia:

"In addition to the engineer and four machinists now authorized, there shall be allowed the naval brigade an engineer division, consisting of four water tenders, who shall rate with quartermasters; four oilers, who shall rate with coxswains; and twenty firemen, who shall rate with seamen. These petty officers and men shall be attached directly to brigade headquarters and, for them, the brigade commander shall be recruiting officer. They shall be armed, equipped and uniformed as the Commander-in-chief shall designate, and without expense to the men. They shall, if applying therefor, receive an annual compensation of $25, and in addition thereto, $2.25 for each day's duty ordered by the commanding officer of the brigade, when approved by the Commander-in-chief.

"They shall be assembled at least twice monthly for such drill

in infantry, artillery and in boats as the brigade commander shall elect, and when so assembled, or when on duty as a division on board ship, they shall be commanded by the brigade engineer, or by a machinist designated by the commanding officer of the brigade.

"Any petty officer or man, in the engineer division thus allowed, may be fined an amount not exceeding $3 for each and every day's absence from any ordered tour of duty, and such fine may be collected by the commanding officer of the brigade through ordinary process. In all other respects, the petty officers and men of the engineer division shall be subject to the regulations and orders governing the naval brigade, Massachusetts Volunteer Militia."

Should it be deemed inexpedient or impractical to thus enlist oilers, water tenders and firemen, it would still, doubtless, be possible to include an engineer officer and several machinists on the staff of each organization of the naval militia, and these could be so selected as to insure their furnishing firemen as needed. But, in every way, the regular enlisting of firemen is preferable, and presents the special advantage of incorporating into the militia a body of men, citizens if you will, who would hardly become interested in our militia in any other way.

In conclusion, may I venture to ask that those, who have honored me with their attention, will honor me yet the more by at least considering the establishment of an engineer force in their several organizations. We are banded together to serve a common cause and a common country, and let us trust that our reasoning together shall be of avail.

The time may be close at hand or yet distant, when our Nation's need may summon us, but surely in *all* things it is well to be prepared, and if prepared by earnest purpose, by proper equipment, by drill and organization, we cannot fail to maintain the right to our inheritance, nor to justify the voice of our people that shall bid us "be strong, quit yourselves like men."

[The bill relating to the Massachusetts naval brigade was approved by the acting governor of Massachusetts on March 28, 1896, substantially as proposed in the above paper.

It provides for the organization of engineer, torpedo and signal divisions, to be attached to brigade headquarters. The engineer division, which had already been provisionally organized, was formally mustered in on the same day, Lieut. A. B. Fry, the commissioned engineer officer, being placed in command. The four machinists were already in the brigade. The water tenders and oilers are taken from the members of the Association of Marine Engineers and the Association of Stationary Engineers, the firemen being selected from the principal electric, pumping and engineering plants in Boston and vicinity.

In the provisional engineer division, these men were enlisted as "seamen," and then detailed when occasion required. The present form of organization is much better in all ways.—EDIT.]

CALCULATION OF HORSE-POWER FOR MARINE PROPULSION.

By Lieut. Colonel Thomas English.

[Read before the Institution of Mechanical Engineers, January 30, 1896.]

The author desires to call attention to a method of calculating, from the results of a single sea trial of one ship, the horse-power necessary to propel another ship, of the same type, at any required speed. By this method it becomes practicable, with the ordinary appliances of a shipyard, to approximate closely to results which could otherwise be obtained only by the use of the refined apparatus of a model tank.

It is generally agreed that the most accurate method at present known of estimating the resistance of a ship at any particular speed is that worked out by the late Mr. William Froude, which consists in separating the part of the resistance due to skin friction from the part due to wave and eddy making. The skin friction varies with the length, area and nature of the wetted surface, and with a power of the speed less than the square, in such a way that it can be readily tabulated, whilst it is independent of the displacement. The residuary resistance caused by wave and eddy making cannot be so dealt with, and at present can be satisfactorily ascertained only by trial, either of an actual ship at sea, or of a model in a tank. When this is done the residuary resistance at one other corresponding speed can be calculated for any ship or model of the same shape, but of different displacement, according to Froude's law of comparison. This law is equivalent to the statement that, if the speeds of a model and of the ship which it represents are made proportional to the sixth roots of their respective displacements, the residuary resistances at these corresponding speeds will be proportional to the displacements.

Principle.—The method about to be described is based upon the self evident proposition that it will always be possible to make two models on such scales that, according to Froude's law, the same absolute speed will for one of the models correspond with that of a ship which has been tried at sea, and for the other with that desired for a proposed ship. The actual resistance of the model of the ship already tried at sea can be calculated by Froude's method; and if the ratio of the total resistances of the two models at the same speed is found by trial, the actual resistance of the second model will be known. From this, also by Froude's method, the resistance of the proposed ship at the desired speed can be calculated. The details of the calculation are as follows: If the total resistance of a ship of displacement D_1 at any speed V_1 be ascertained by trial, and it is desired to find the total resistance of a ship, on either the same or different lines, of displacement D_2 at a speed V_2; let models of the two ships be made, of displacements d_1 and d_2 such that

$$\frac{d_1}{d_2}=\frac{D_1}{D_2}\times\left(\frac{V_2}{V_1}\right)^6,$$

and let the following be corresponding quantities for the ships and models:

Wave Resistance.	Skin Resistance.	Displacement.	Speed.
W_1	S_1	D_1	V_1
W_2	S_2	D_2	V_2
w_1	s_1	d_1	$V_1\left(\frac{d_1}{D_1}\right)^{\frac{1}{3}}$
w_2	s_2	$d_1\times\frac{D_2}{D_1}\left(\frac{V_1}{V_2}\right)^6=d_2$	$V_1\left(\frac{d_1}{D_1}\right)^{\frac{1}{3}}$

Also let n be the ratio of the total resistances of the models at the same speed $V_1\left(\frac{d_1}{D_1}\right)^{\frac{1}{3}}$.

Then

$$w_1=W_1\times\frac{d_1}{D_1}$$

$$w_2+s_2=n\,(w_1+s_1)$$

$$w_2 = n\,W_1 \times \frac{d_1}{D_1} + ns_1 - s_2$$

$$W_2 = w_2 \times \frac{D_2}{d_1 \times \frac{D_2}{D_1}\left(\frac{V_1}{V_2}\right)^6}$$

$$= \left(\frac{V_2}{V_1}\right)^6 \times \left\{ n\,W_1 + \frac{D_1}{d_1}(ns_1 - s_2) \right\}$$

and the total resistance of the ship of displacement D_2 at the speed V_2 will be

$$S_2 + \left(\frac{V_2}{V_1}\right)^6 \times \left\{ n\,W_1 + \frac{D_1}{d_1}(ns_1 - s_2) \right\}$$

from which the required horse-power can be obtained.

The values of S_1, S_2, s_1, s_2, must be calculated from tables of skin resistance. The value of W_1 must be deduced from the indicated horse-power required to propel the vessel D_1 at the speed V_1, using an appropriate co-efficient for the ratio $\frac{\text{thrust horse-power}}{\text{indicated horse-power}}$.

The value of n is obtained by attaching the models to the two arms of a horizontal lever, and towing from the fulcrum at a speed $V_1 \times \left(\frac{d_1}{D_1}\right)^{\frac{1}{6}}$; the relative lengths of the lever arms being adjusted by trial, until the models tow steadily abreast. As this value of n can be obtained without knowing the actual resistance of each model, the delicate dynamometrical apparatus which forms one of the chief features of a model tank may be dispensed with, and the final result is arrived at by simple means.

Apparatus.—In the diagrams, Figs. 1 and 2 show an apparatus which has been found to answer well for this purpose. It consists of a small electro-motor, furnished with a resistance coil, and running at from 900 to 1,000 revolutions per minute. At this speed the motor is adjusted to give off about one-sixth of a brake horse-power, or a pull of about 8.4 pounds through 631 feet per minute on an endless piano wire, No. 18 music-wire gauge, or 0.036 inch thick, stretched over two pulleys 11⅝ inches in diameter on horizontal axes about 350 feet apart. One

of these pulleys is connected with the motor shaft by belting on a pair of driving pulleys; and the other is arranged to stretch the wire by means of a weight, until the sag does not exceed 3 or 4 inches. The pulleys are supported by staging, so that the wire between them is suspended horizontally over the surface of any convenient sheet of water, such as a partially filled dry dock, not less than 5 or 6 feet deep.

The towing frame is composed of steel bicycle tube, and consists of two similar and parallel levers, each 60 inches between centers, pivoted at their ends to the decks of the models, so that the latter will always be parallel to each other. The levers are graduated into 1,000 divisions of nearly $\frac{1}{16}$-inch each, and are attached by short collars, which can be clamped, at any required graduation, to pivots at the ends of a bar, which is of the same length—4 feet—as the distance between the pivots on the deck of each model. This bar carries a vertical spindle, to which the lower wire is connected by a ring that can travel up and down the spindle, and thus allow for the sag of the wire. Vertical slotted guides embrace the wire at both ends of the bar, and thus keep the bar, and therefore the models, in a straight course. The details of the towing frame are shown in Fig. 3 for the transverse levers and in Fig. 4 for the longitudinal center bar.

The models, the larger of which is about 10 feet long, are made of yellow pine, of ordinary shipyard workmanship, and are ballasted with lead to the required draught and trim; they are well painted, rubbed down, and varnished. Loose diagonal cords connecting the models serve as stops to prevent them from coming close together when one lags behind the other. The levers are always clamped at the same graduation on each; and this is varied by trial, until the models tow abreast at the required speed. It is found that a variation of $\frac{1}{8}$ inch, or 0.002 of the total length of the lever, produces a sensible effect upon the result; and that the requisite speed can readily be obtained within limits of $\pm$ 0.02 knot per hour. The models are brought to rest by disconnecting the motor switch and applying a brake, and after a run are towed astern to the starting platform by crossing the belt on the driving pulleys.

Example.—The following example will show the application of this method to determine the horse-power required for a torpedo destroyer of 300 tons displacement and 30 knots speed, on the lines of H. M. S. *Janus* and *Lightning*, built by Palmer's Company, Jarrow, of 247 tons displacement and 27.85 knots speed on trial.

The linear dimensions will be increased as $\left(\frac{D_2}{D_1}\right)^{\frac{1}{3}}$ or as $\left(\frac{300}{247}\right)^{\frac{1}{3}}$ or as $\frac{1.067}{1}$. The corresponding speed $V_1\left(\frac{d_1}{D_1}\right)^{\frac{1}{6}}$ of a model of the *Janus* on $\frac{1}{20}$th scale will be $\frac{27.85}{\sqrt{20}} = 6.23$ knots. The scale of a model of the proposed ship, for which 6.23 knots is the corresponding speed to 30 knots for the full-sized ship, is

$$\left(\frac{6.23}{30}\right)^2 = \frac{1}{23.21}.$$

The wetted surface of the *Janus* is 3,796 square feet.

The wetted surface of proposed ship is $3{,}796 \times 1.067^2 = 4{,}321$ square feet.

The wetted surface of $\frac{1}{20}$ scale model is $3{,}796 \times \frac{1}{20^2} = 9.49$ square feet.

The wetted surface of $\frac{1}{23.21}$ scale model is $4{,}321 \times \frac{1}{23.21^2} = 8.02$ square feet.

Hence from tables of skin resistance,

$S_1 = 0.0094 \times 3{,}796 \times 27.85^{1.83} = 15{,}720$ pounds.
$S_2 = 0.0094 \times 4{,}321 \times 30.00^{1.83} = 20{,}500$ "
$s_1 = 0.01124 \times 9.49 \times 6.23^{1.85} = 3.15$ "
$s_2 = 0.01124 \times 8.02 \times 6.23^{1.85} = 2.66$ "

Indicated horse-power of *Janus* at 27.8 knots = 3,840.
" " *Lightning* at 27.9 " = 3,990.
Mean indicated horse-power at 27.85 " = 3,915.

If the coefficient $\frac{\text{thrust horse-power}}{\text{indicated horse-power}}$ be taken as 0.6, the mean thrust horse-power = 2,349.

Hence $W_1 + S_1 = \frac{2,349 \times 33,000 \times 60}{27.85 \times 6,080} = 27,467$ pounds.

$$W_1 = 27,467 - 15,720 = 11,747 \text{ pounds.}$$

It is found on trial that the ratio of the total resistances of the models is

$$n = \frac{w_2 + s_2}{w_1 + s_1} = 0.811.$$

Hence the total resistance of the proposed ship

$$W_2 + S_2 = S_2 + \left(\frac{V_2}{V_1}\right)^6 \times \left\{ n W_1 + \frac{D_1}{d_1}(n s_1 - s_2) \right\}$$

$$= 20,500 + 1.077^6 \times \left\{ 0.811 \times 11,747 + 8,000(0.811 \times 3.15 - 2.66) \right\}$$

$$= 34,000 \text{ pounds.}$$

$$\text{Thrust horse-power} = \frac{34,000 \times 6,080 \times 30}{33,000 \times 60} = 3,132 \text{ H.P.}$$

$$\text{Indicated horse-power required} = \frac{3,132}{0.6} = 5,220 \text{ H.P.}$$

So long as the ratio $\frac{\text{thrust horse-power}}{\text{indicated horse-power}}$ remains the same for both ships, its assumed value may be varied between wide limits. Variation in the speed of towing, or in the condition of the surfaces, provided they are the same for both models or for both ships, may also take place without materially affecting the result.

In Fig. 5, the method of calculation is shown in the form of a diagram, in which abscissæ represent speeds in knots, ordinates measured downwards from the zero line represent skin resistances in pounds, and ordinates measured upwards represent wave resistances in pounds. The points indicated in the curve for the *Janus* represent the results of a series of speed trials at approximately the same displacement. The curves of resistances of models show the results when the speed varies with the sixth root of displacement, whilst the same lines are retained throughout. If the diagram were carried back far enough to

show the actual speed of 6.23 knots, at which the models were towed, the ordinates representing their resistances would not be distinguishable on any reasonable scale; but the ordinates at any point within the limits of the diagram will equally represent the resistances of an assumed pair of models, increased in displacement as the sixth power of speed.

If by means of a tank experiment the total resistance $w_1 + s_1$, of a floating body of any convenient shape and size, towed at a speed v_1, be ascertained, this resistance may afterwards be used as a standard for obtaining, by the apparatus described, the comparative resistance of a model made to the scale $\left(\frac{v_1}{V_2}\right)^2$ of any proposed ship whose speed is desired to be V_2.

Then

$$W_2 = w_2 \times \left(\frac{V_2}{v_1}\right)^6 = \left(\frac{V_2}{v_1}\right)^6 \left\{ n(w_1 + s_1) - s_2 \right\}$$

and the total resistance of the proposed ship will be

$$S_2 + \left(\frac{V_2}{v_1}\right)^6 \left\{ n(w_1 + s_1) - s_2 \right\}.$$

It is obvious, however, that the calculation of indicated horse-power from this result is much more dependent upon the accurate estimation of the ratio $\frac{\text{thrust horse-power}}{\text{indicated horse-power}}$, and of the speed v_1 and the condition of the surfaces, than it is in the method first described.

Discussion.

The discussion (from "Engineer's Gazette," Newcastle,) was opened by the reading of a letter from **Mr. Froude**, in which he said the method proposed was ingenious, and the advantage in the system rested in the fact that the two elements which are most difficult to estimate were approximately common to both models. He, however, suggested that when towing models of 10 feet long alongside each other, with a distance of nearly four feet between them, their respective waves might interfere with the result.

Professor Barr said that if the resistances were not exactly equal while the models were being towed, instability might result, and the models would come together. He also had thought that the point made by Mr. Froude might arise in regard to the models interfering with each other. He would ask if there was any advantage in cost of production in using wood models over those made of wax, which were generally employed in tank experiments.

Mr. Leslie Robinson referred to the examples given by the author in the paper, in which he determined the horse-power required for a torpedo boat destroyer of 300 tons displacement and 30 knots speed. The *Janus* and *Lightning*, built by Palmer's Company at Jarrow, had displacements of 247 tons, and they steamed on trial at 27.85 knots. The wetted surface of the *Janus* was 3,796 square feet; on the proposed vessel it would be 4,321 square feet. The indicated horse-power of the *Janus* at 27.8 knots was 3,840; whilst the *Lightning*, steaming at 27.9 knots, required 3,990 indicated horse-power. Working these figures out, the estimated horse-power required for the 30-knot vessel would be 5,220 horse-power. Referring to these figures, Mr. Robinson asked whether the details of the calculations set forth had been obtained by means of actual experiments from models. He asked this because the horse-power to give the speed seemed low, those accustomed to designing vessels of this class would give rather 6,000 indicated horse-power.

Colonel English, in replying, said, with regard to the distance apart of the models, and the interference of the waves thrown off by them, he had settled the distance from observation of the waves of an actual ship on trial. The distance was measured of the waves going out at the stern, and the models were adjusted accordingly. It was an illustration of the beauty of Froude's system that corresponding speeds in models reproduced the actual wave formation made by the full-sized ship. Photographs had been taken of waves formed at sea, and the models in the tank were found to reproduce them. Professor

Barr had asked if the models closed together when the levers were unequal. He had not observed that, but as he had said, there were diagonal guides for preventing this difficulty, and thus the models were prevented from coming too close together. The trial referred to in the paper consisted of 11 runs, and all the time the models kept almost exactly abreast, and when the speed was adjusted they were perfectly equal over the whole course. The advantage of wood over wax for models for shipyard work was that the ordinary workman employed could deal with the material. In regard to the proportion of horse-power allotted to the 30-knot boats, he thought that with 300 tons displacement the power would be as specified.

Fig. 1.

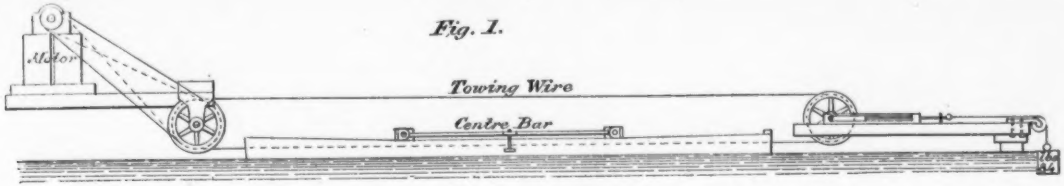


Fig. 2.

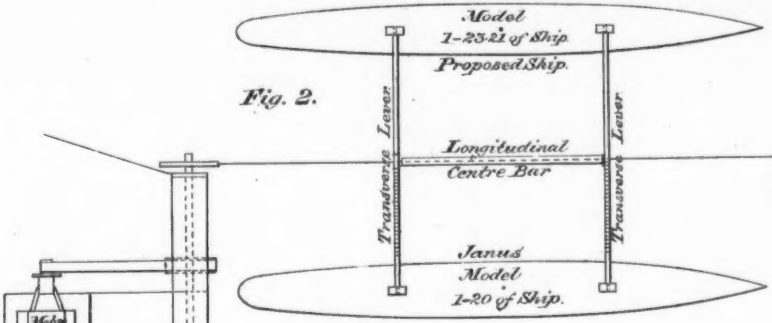


Fig. 3.

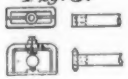


Fig. 4.

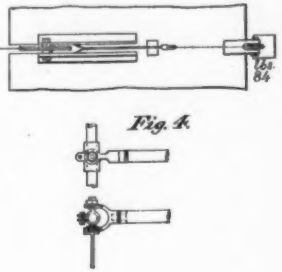
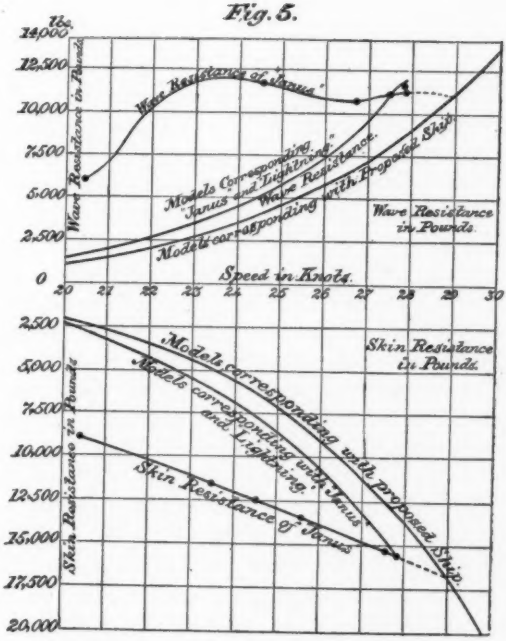


Fig. 5.


lbs.
14,000
12,500
10,000
7,500
5,000
2,500
0
Wave Resistance in Pounds
Wave Resistance of "Janus"
A
Models Corresponding "Janus and Lightning"
Wave Resistance.
Models corresponding with Proposed Ship
Wave Resistance in Pounds.
Speed in Knots.
20
21
22
23
24
25
26
27
28
29
30
2,500
5,000
7,500
10,000
12,500
15,000
17,500
20,000
Skin Resistance in Pounds
Models corresponding with "Janus" and "Lightning"
Skin Resistance of "Janus"
Skin Resistance in Pounds.

WATER TIGHT DOORS, AND THEIR DANGER TO MODERN FIGHTING SHIPS.

By Captain the Right Hon. Lord Charles Beresford, C. B., R. N.

[Read at the Thirty-seventh Session of the Institution of Naval Architects, March 25, 1896.]

The country is now thoroughly aroused to the fact that the punctual and certain delivery of our food and commerce, and even the existence of our Empire, depends absolutely on our command of the sea. Hostilities may be commenced by an attack upon weak points by torpedo fleets, by mining fairways, by the attempted destruction or interruption of commerce by cruisers or torpedo boats or even, indeed, by the levying of indemnities upon undefended towns; but whatever the result of these preliminary efforts, the ultimate issue of a naval campaign must depend upon the defeat or success of the battleship fleets. It therefore becomes imperative that nothing which human foresight can conceive should be left undone to insure that the individual ships of the battleship fleet will resist as long as possible the three modern elements of danger to be faced in action, *i. e.*, the gun, the torpedo and the ram; and also those unforeseen contingencies inseparable from the life of a fighting ship whether in peace or war. It appears to me that every effort has been made, as far as human ingenuity has gone at present, to secure a ship floating after a severe gun action, but equal attention has not, in my opinion, been paid to this consideration in the event of a ship being badly wounded by ram or torpedo. It is to reduce the probability of losing a vessel through the agency of these "elements" that I make the following proposals.

A battleship is a variety of compromises, and water tight doors form one of those compromises. The water tight door compromise may be defined in the following manner: It is the safety of

the ship *v.* the convenience of the departments. In my opinion the safety of the whole ship is infinitely more important than the convenience of the different departments. According to the system which obtains at present we put ourselves to great trouble, inconvenience, and expense, and add enormously to the weight of our ships (a most material point) by building a large number of bulkheads athwartships, and fore and aft, to ensure her safety when wounded below the water-line. Then, in order to defeat our original object, we cut a great hole (often two) in each bulkhead for the convenience of the different departments on board, and so practically reconvert the ship into one compartment. It has so often been proved that the holes are invariably open when an unforeseen contingency occurs.

I am well aware that this matter has been one of continual debate and discussion amongst the separate departments, the seaman, the constructor and the engineer, who have to use their expert knowledge in deciding the many complex and tremendously difficult problems involved in the construction of a battleship. I am therefore somewhat diffident about putting forward my idea in the face of the expressed opinion of the constituted authorities, who have devoted their energies to the consideration of this matter; but, having for some years given this subject my earnest attention, and knowing the opinion of a very large number of my brother officers, as well as constructors and engineers outside the Service, I have come to the conclusion that there is a great diversity of views on the water tight door question. In view of this diversity of opinion, and the fact that the French have almost entirely done away with water tight doors in their new ships, I venture to lay my arguments in favor of a reduction in the number of water tight doors before the highest community of experts on such a matter that the country can produce.

It is a fact that upon the loyalty of water tight doors when closed, and upon the assurance that they *are* properly closed, depends the power of a battleship to float when wounded by ram, torpedo, or possibly the gun. In war time our ships will not always be in action, but they will nevertheless be exposed to dangers (princi-

pally of submarine explosions) which may be totally unlooked for, and in the nature of a complete surprise.

Although all water tight doors would be closed on going into action, it is possible, indeed probable, that all, or many of these might be open for ventilation or convenience, when one of the unlooked for contingencies I have suggested occurred. It has been authoritatively stated, for instance, that the cause of the loss of the *Victoria* was that the water tight doors were not closed, and it has been constantly proved to be impossible to close water tight doors in an emergency, no matter how well disciplined, and how gallant the ship's company may be. The splendid, but unavailing heroism of the officers and men of the *Victoria* was a shocking and terribly convincing proof. Other evidence exists, namely, *Re d'Italia* ramming at Lissa, *Vanguard* and *Grosser Kurfürst* sunk by collision in peace time during manœuvres, and *Blanca Escalada* sunk by torpedo. It was reported in each case that, had it been possible to close the doors in time, the ships would have been saved. I believe it to be a fact that no ship has been saved when wounded below water-level at a moment when her water tight doors were open. If doors be open in an unforeseen contingency, or when the ship is rammed or torpedoed, it is allowed that the ship is in danger. The possibility is that her doors may be open. Hence the danger of having the doors at all.

I propose to avoid the danger of that possibility by (1) doing away altogether with the greater number of the doors, and (2) by so modifying the size and position in bulkhead of some of those which remain, as to prevent a sudden rush of water being immediately distributed through different compartments in the ship, as occurred in the *Victoria*.

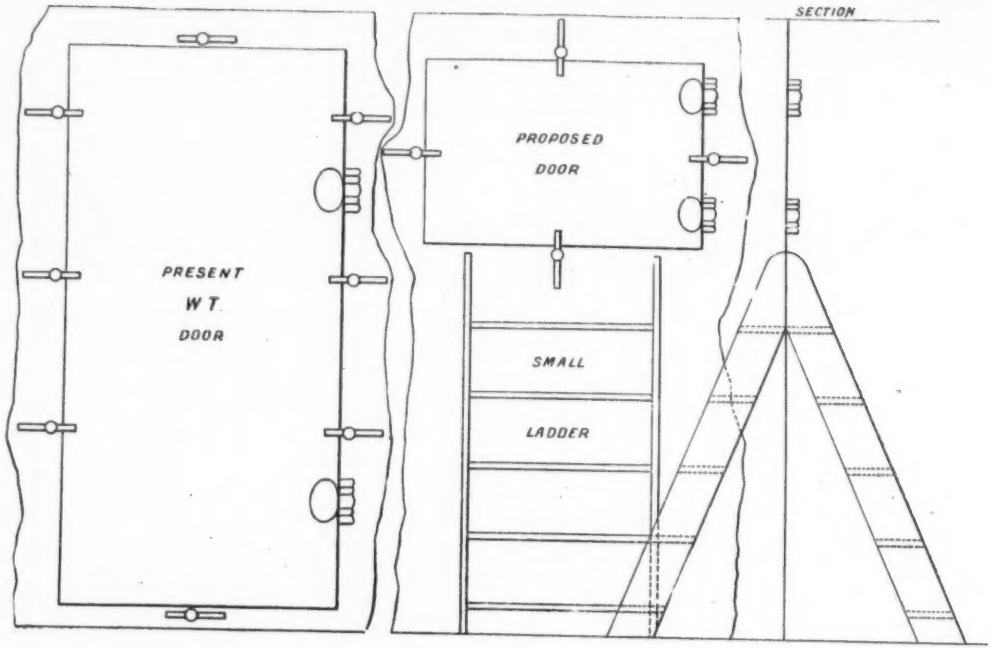
The total number of doors in each of the following ships is :— *Magnificent*, with 150 compartments, 208 doors ; *Royal Sovereign* and *Repulse*, 187 compartments with 148 doors ; *Rodney* and *Anson*, 121 compartments and 98 doors ; *Theseus* and *Hawke*, 122 compartments and 98 doors ; and the *Agincourt*, 29 compartments and 17 doors. The old ships have few compartments, but much less doors in proportion.

The following list gives the number of doors in ships of the *Magnificent* class dealt with according to my suggestion :—(1) Doors I propose should be done away with, 19; (2) doors I suggest should be modified in accordance with my proposals, 23; excepting ammunition passage doors and (3) doors in which no alteration is proposed, 22.

(1) By far the most important doors to do away with, in my opinion, are all on all decks below water line between 63 and 105 stations—which bulkheads enclose the engine room and boiler room compartments. I agree that quick communication is necessary between the engineer officer and his subordinates, but quick verbal communication is all that is required; and, in my opinion, all demands could be met by a small scuttle. These compartments form the belly of the ship—the great floating power from which she gets her buoyancy. In case of one of them being flooded with water, or filled with steam from a fractured pipe, or other cause, the water or steam is immediately communicated to the whole belly of the ship owing to the impracticability of closing the water tight doors in an emergency—as shown by the examples quoted. Now not only is each athwartship bulkhead pierced by a door (often two), but the midship bulkhead also has often two in each compartment. The next most important place is, in my opinion, right forward, where water tight doors should be done away with altogether in collision bulkhead, and I think they should also be done away with in the next bulkhead abaft, in order to be still comparatively safe if the collision bulkhead gives way. In fact, no opening whatever, either sluice valve or anything else, should exist in this bulkhead. The only way to get to the foremost compartment should be by a manhole in deck above.

[Incidentally it might be mentioned that I think (1) it would be advisable to shift the collision bulkhead further aft, so that it should be quite clear of all the strengthening pieces supporting the ram; (2) that it should be far more strongly fitted than it is; and (3) that it should be rounded like a barbette instead of being at right angles to the side.]

(2) In the case of the doors I propose to modify, the large



Scale 1"-1'

doors should be replaced by small rectangular openings close up to the deck, at the top of the bulkhead, as shown in sketch. This proposal is intended to allow officers and men to get from one compartment to another quickly if necessary. The merit I claim for this fitting may be exemplified in the following manner :—If a ship be wounded by torpedo or ram in a compartment below the water line, the water will rush in with irresistible violence. With the present system of water tight doors, where the sill is nearly level with the deck, there is nothing to prevent the water rushing to all parts of the ship at once, and it becomes impossible to close the doors.

With my proposal the water meets a solid bulkhead all round the compartment to a height of five, six, or more feet, according to the height of compartments. The water is confined for some appreciable time in one space, and this gives ample time to close and secure the " rectangular opening " at the top of the bulkhead. Another point of advantage I claim for this suggestion is that bulkheads having small openings in them must, on the face of it, be stronger than bulkheads having large doors, reaching for nearly their whole length, from deck to deck. In the event of a ship being rammed, the violent blow will not only disturb bulkheads locally, but is certain to disturb bulkheads at some distance from the point of impact. Bulkheads with small openings as proposed are certain to withstand the shock better than bulkheads having large apertures as at present.

If a ship be wounded by torpedo or ram in a compartment above and near the water line (so that water can enter), the utility of my proposal is equally great, as the solid bulkhead will confine the water to one locality. Even were the water tight doors closed in battleships, I have no faith in the strength of the fore-and aft bulkhead in engine and boiler rooms Even when strengthened by Z-angle irons, as has been done lately, it is not strong enough; and the test for this bulkhead should, in my opinion, be far more stringent than that now employed, *i. e.*, being pumped on with a hose.

(3) In the case of the doors in which no alteration is proposed, they are necessary for the fighting efficiency of the ship, as there

are certain places where doors are necessary (such as for the supply of ammunition), and in bulkheads of compartments, that have no ladderway or escape through deck overhead. It is no use arming ships with quick firing guns unless the line of communication from the magazines to the guns allows for constant supply and quick delivery.

There are only seven doors in the whole ship below the water line that, in my opinion, should remain. The doors that are necessary should, I think, be improved. I cannot conceive a worse principle than is employed for closing the hinged doors in the British Navy. The hanks and butterfly nuts have each one to be secured or screwed up separately. The consequence is that in a panic or sudden emergency, you invite an accident, as it is unlikely that men will remain to secure each hank and each butterfly nut, without which the door cannot be effective. I have seen many doors, a great deal better than the ones employed in the Navy, of the same weight and about the same price. The principle that should be enforced is that it should be possible to shut the door and secure it in one movement.

Owing to the length of my paper, I do not propose to enter into details conerning the doors of the other classes of ships I have named, but I am most strongly of opinion that in fighting ships of all classes the suggestions I have made should be carried out in each ship building, and that ships built should be altered in the direction I advocate. It is only by using foresight that possible, and I consider probable, dangers may be avoided.

In the very latest class of ship building (*Terrible*) we appear to have gone more mad on water tight doors than in any other class. The engines and boilers in the belly of the ship are in ten different compartments, and in these ten different compartments there are sixteen doors. A system of construction that appears to me to be simply risking the safety of the ship by preventing the bulkhead from carrying out the object of its existence.

It will be argued that owing to the excellence of our drill and discipline it is possible, from constant practice, to close these doors in time to save the ship after an accident has occurred. I

entirely disagree with this, and have given proofs that it cannot be done. The system of closing doors by evolution as to time invites an accident. As all captains well know, the men will run down, if allowed, heave one or two hanks over a vertical door, or let fall a horizontal door without screwing up all butterflies and report it closed, which is true, but the door is not properly secured. If the water got the wrong side of the bulkhead or deck, the door would immediately burst open. The argument that my proposals will affect the ventilation of the ship cannot be sustained in these days of mechanical ingenuity for overcoming difficulties.

Lately—within a few weeks—I paid a visit to Toulon, and was greatly struck to find that the two new French ships, *Carnot* and *Jaureguibery*, building there, have been constructed, so far as the water tight door question goes, almost exactly as I have advocated for some years. These ships have not one single compartment that goes right across the ship. Their six boiler and two engine rooms are entirely cut off from any communication with each other, except by voice tube. The only ingress or egress is by small rectangular openings at the top of the bulkheads, and level with top of boiler in boiler room, and top of cylinder in engine room. To get from one to another it is necessary to go up a ladder, cross a deck, and then descend again. Even their submerged tubes are in separate water tight rooms with solid bulkheads, instead of both being in one great space with doors in it, according to the English custom. Moreover, the fore-and-aft bulkheads are far more strongly secured than ours. Every three feet there is a heavy H iron (like a railway rail) bolted vertically to bulkheads. They have also the same principle in use with regard to small openings in bulkheads above the water line, as I advocate. These openings are oval, and on the top of a combing about 4½ feet high. It is necessary to put one foot through and then your bent head, to get from one compartment to another.

The French ships, owing to the disposition of their weights, are not so stable as our ships, and it may therefore be argued that, with this knowledge, they divide their ships into smaller

and more numerous compartments. But, though our ships may be more stable, I prefer to localize the water as much as possible when it does enter through the effect of a wound.

I most earnestly commend to the attention of the Institution of Naval Architects the views I have enunciated in this paper. I maintain that, with such practical facts as the *Victoria*, &c., staring us in the face, we are quite wrong to continue the system of water tight doors at present adopted in our Navy, particularly in the case of battleships.

The battleship fleet upon which we most rely, consists of only twenty-two ships (I speak of the modern ships), out of which seven cannot be ready for the pennant for a year or more. I do not count the twelve light-ended ships, as I consider if they get into "close action" they will go down bottom up after the first twenty minutes; and I do not count the fourteen battleships armed with muzzle-loading guns, as there is no place you could put them in an action where they would have a chance even against small cruisers, armed with modern breech loading quick firers, as the small cruiser has not only the advantage of speed, but of range as well. Therefore, do let us be perfectly certain that there is, as far as human foresight goes, no weak point in those ships upon which we do depend, and which should have the power to keep afloat under almost any contingency.

SUMMARY.

The summary of my contentions is:

(1) Many water tight doors can be abolished. This would add to the safety of the ship.

(2) Many water tight doors can be modified with the same advantage.

(3) That where water tight doors are necessary of their present size, they should be constructed on a better principle than those we now use.

(4) That all these alterations in construction can be carried out without affecting the fighting efficiency of the ship.

My object in writing this paper is to invite discussion from those shipbuilding experts who are best able, by argument, to

prove that those who agree with me on this all-important question are right or wrong.

[NOTE.—For abstract of the discussion on this paper, see the end of the following paper.—EDIT.]

WATER TIGHT DOORS.

BY COLONEL N. SOLIANI, DIRECTOR OF NAVAL CONSTRUCTION, ROYAL ITALIAN NAVY, MEMBER.

[Read at the Thirty-seventh Session of the Institution of Naval Architects, March 25, 1896.]

The subject of water tight bulkheads, in relation to the safety of ships, has been fully dealt with in various valuable papers read before this Institution; but, as far as I am aware, not sufficient importance has been given to water tight doors, on the efficiency of which so much of the efficiency of the bulkheads themselves depends.

That things in this matter are not satisfactory is made apparent, not only by sad disasters, but by the general opinion that a water tight bulkhead, to be really efficient, ought to have no water tight doors whatever. Of course much of this feeling is due to daily experience, showing that the human factor is not always to be relied upon. And, of course, strong and perfect bulkheads and water tight doors are of no use when the latter are neglected, or left open unnecessarily, or when no sufficient drill is practiced on board to secure their being shut quickly when needed. But, apart from this, a good deal of distrust is still due to the doors not being always made in the best way to secure promptness of action and efficiency. And the scope of this paper is to pass in review the various systems of water tight doors adopted, and to draw from it the requisites which the latter ought to satisfy to secure the best practical results in the conditions of service under which they are to act. It is at sea that these conditions principally manifest themselves, and it is specially at sea that danger

exists and the functions of water tight doors have occasion to and must exert themselves in the most efficient way.

In respect to the said conditions, water tight doors may be divided into three classes:

(*a*) Water tight doors, at or below water line which, in a sea way, can be kept always completely shut, or if needed open it is only occasionally and for a short time, after which the doors can be restored to their shut up position. Water tight doors well above water line.

(*b*) Water tight doors below water line, between compartments, such as the engines and boiler-room compartments, through which communication when the ship is at sea is permanent or practically so.

(*c*) Bunker water tight doors, which not only are to be kept open in a seaway, but are also liable to be jammed by coal when closing.

HINGED WATER TIGHT DOORS.

Water tight doors under head (*a*) do not require to close quickly, and, therefore, are usually made hinged, in which form a good, simple, light and efficient water tight door can be obtained.

Figs. 1, 2 and 3 show how these doors are generally made. The hinged door has, all round its edge, screw or lever latches to keep the door when shut well tight against the seat frame. For bunkers above protective decks screw latches are preferred, all independent and worked only from one side, as in Fig. 1. The seat frame is generally fitted with india rubber or tuck packing, but when absolute tightness is not necessary, as is the case with coal bunker bulkheads above protective decks, or with doors well high above water line, the packing can be dispensed with, the seat being then a simple solid frame of rectangular section, as shown in Fig. 2. These solid frames, while efficient, are economical, as they dispense with the packing, which is expensive and subject to rapid deterioration. Various packings, other than india rubber or tuck packings, such as cotton packing in a natural condition or well greased, leather, &c., have been tried; but, so far, none of them have yet been found to combine durability,

efficiency and cheapness in the desired degree. Doors in passages through bulkheads have lever latches workable from both sides, as in Figs. 2 and 3. These latches, when the doors are well above water line—as passage doors on main decks—may be fitted only along the edge opposite to the hinges and connected all to one handle, in which way they can be worked together at one time (Fig. 2). Latchless doors have also been resorted to. In this case they are double, viz., they have two shutters working opposite one to the other on the two sides of the bulkhead, so that whichever side is flooded there is always one of the two shutters pressed to close by the pressure of the water itself. Suitable springs cause both shutters to close when released after having been opened. These doors are said to be handy and efficient.

SLIDING WATER TIGHT DOORS.

Water tight doors under head (*b*) require efficiency and quickness combined. Therefore, they are usually made of the sliding form, and workable both from the door itself and from the decks above. They are made to slide vertically or horizontally, according to space available; but vertical sliding is preferred, when possible, as the door can be made comparatively simpler and lighter. Some people are of opinion that vertical sliding is also preferable, as being faster when closing, but, with proper arrangement, horizontal sliding need not be inferior in this respect, while certainly it offers greater easiness of manœuvre when opening. This point is worth consideration, and will be dealt with more fully later on. When horizontal, the doors slide on running wheels, by which they can be worked rapidly, both when opening and closing, without being subject to jam, as is the case when they slide on the guides.

The wheels are fitted in such a way as to be get-at-able for inspection and repair.

Horizontal sliding doors are generally worked by a rack and pinion gear, the rack being fitted to the door and the pinion to a vertical shaft leading to the main deck above. A hand key, which is kept always ready near or on the door itself, can be

quickly geared on the pinion and used as a handle to work the door from its place. In this way the door can be opened and closed easily by the same person who wants to pass through it—an advantage which is not secured with vertical sliding doors, except by special arrangements.

Fig. 4 shows an ordinary horizontal sliding door, as usually fitted on board ships. The lower side of the door frames of sliding doors, when grooved to form a guide to the shutter, is liable to get choked with dirt, and to prevent this the guide is usually covered with a lid, which opens automatically when the door is closed. To avoid the necessity of this cover, the lower side has generally no guide.

If we turn a horizontal sliding door 90° on its plan, we have a vertical sliding door needing no alteration for its working. However, with vertical sliding, the gear, instead of a rack and pinion, is generally a fixed vertical screw shaft working in a nut attached to the door (Fig. 5.) With this arrangement the movement of the door is slow, both when opening and closing. Such slowness is not convenient, specially when closing, which operation, in time of emergency, ought to be as quick as possible. To secure this result various devices have been resorted to, a usual one being an eccentric or some similar apparatus by which the nut is thrown out of gear when the door is to be shut. Then the shutter falls down quickly by its own weight (Fig. 6). (This implies, of course, that the door is closing when the shutter is lowered, as is generally the case.)

The disengaging gear, as above described, is open to two objections: (1) When released it leaves the door free to fall suddenly, and gives no means of checking or regulating the descent; therefore it is dangerous, as the door may be released just at the moment a person is passing through. (2) When the shutter is down it is sometimes not easy to put the nut in gear again to force the shutter well against the seat frame. To avoid these defects, in lieu of the nut a brake is fitted to the door, as in Fig. 6, or two worm wheels with locking brake are fitted, embracing the screw shaft (Fig. 7). These wheels are locked fast when the shutter is raised, but can be made loose at any convenient de-

gree when the shutter is lowered. When locked they act like a screw nut, in which a screw shaft is revolving. When loose, they simply turn freely and glide along the screw shaft. Therefore, the shutter can be regulated at will on its descent, and can be forced tight against the seat, when down, by simply tightening the locking brake when the screw shaft can be used to force the shutter.

The tightening brake can be locked both from below and from above deck as convenient. The gear, whether rack and pinion or screw shaft and screw nut, is usually worked by hand, but now that electric power is generally available on board ships, the said manœuvre can easily be made by a small electric motor fitted to the hand shaft of each door, as shown in dotted lines on Fig. 8. This arrangement, which has already been fitted on board ships of the U. S. Navy, has two advantages.

(1) The door can be opened and shut instantly by the person who wants to pass through, simply by making and reversing an electric contact.

(2) The closing of all doors that might happen to be open in time of emergency can be effected by a single person—by the officer in command on the bridge. The electric arrangement does not impair the efficiency of the hand gear (which is needed all the same, should the electric current fail), as, when the electric current is interrupted, the electric motor offers but little friction, which can easily be overcome by the hand gear itself.

Possibly the same advantages might be secured in a more reliable and efficient way by using hydraulic instead of electric power. A simple, small, hydraulic cylinder, with reversing valve, fitted to each sliding door and connected to a pipe carrying the compressed water, would be all that is necessary. The force for working a water tight door being comparatively small, a small quantity of water at a very moderate pressure, such as is available on the feed pipes of the boilers of the ship, would be sufficient for the purpose. And, as in a sea way the feed pumps are always at work, the feed water pressure for working the water tight door would be always available and ready. With the

addition of a hand force pump and accumulator to supply the water pressure when the boilers are not at work, the whole arrangement would serve the purpose in a complete way, whether the ship is at sea or in harbor, and, being practical and reliable and of easy maintenance, it could dispense with the hand gear which then would be superfluous. The accumulator need not be large. With a water pressure of 150 pounds, a water capacity of a few cubic feet would be sufficient to work a dozen water tight doors at a time, which number is ample even for a big ship.

The advantages above enumerated are, in my opinion, worth consideration. In fact, why are water tight doors objectionable? Principally because they are kept open. And why are they kept open? Simply because the operation of opening and closing them is tedious and slow and fatiguing. Reverse this condition, give the man who wants to pass quickly through a door the means of opening it rapidly by simply pulling a small lever, let the lever, as soon as it is released, go back automatically and close the door after the man has passed, and then, I think, you will see the sliding water tight doors fulfilling their important function of allowing a free communication between the main compartments of a ship, without impairing the safety of the ship. This refers to passage water tight doors. For bunker doors which are necessarily kept open at sea, the difficulty would also be overcome by the hydraulic arrangement, as by handling a simple main valve the officer in command would be able to close, in a few seconds, all water tight doors that might be open at the time.

A difficulty would still exist, to a certain extent, on board warships, where the bunker holes on protective decks are kept shut. In these ships the coal trimmers, on closing the doors, would be practically shut in the bunkers with no possibility of escape; a condition not very pleasant. And it is this fear of being so imprisoned that has prevented the success of all schemes for suddenly closing the bunker doors, as the coal trimmers, to avoid such an awful fate, contrive means for jamming the doors

to prevent them being shut. Therefore, should any arrangement for closing suddenly the bunker doors be resorted to, it ought to be completed by giving proper means of escape to the coal trimmers.

The sliding shutters of water tight doors, whether for bunkers or for passage through compartments, when shut, are usually forced and kept tight against the seat of the door by means of inclined guides or wedges. This arrangement is open to objections, as the wedges are needless when the pressure of the water acts to keep the shutter self tight against the seat, and they are generally inefficient when the water pressure acting on the opposite side tends to force out and detach the shutter from the seat. Moreover, the guide wedges, to be efficient, must press hard, with the result that the door is then hard to open. To avoid these defects, double seat water tight doors may be resorted to, which are self tight, whichever of the two sides of the door is pressed by the water. Figs. 7 and 8 show two double seat water tight doors, one vertical and one horizontal sliding, as fitted on board the Royal Italian cruiser *Elba*.

Double seat doors are naturally heavier than single ones, but at the same time, they are more robust and rigid, which is advantageous to prevent deformation and insure tightness. There being no wedges to tighten the shutter, as this function is fulfilled by the water pressure itself, the shutter, when the door is shut, in ordinary condition, is free to glide along the guides, with the result that little force is necessary to move it and open the door. On account of this freedom, double seated doors can be also easily balanced with counterweights, in such a way that they will close gently by themselves as soon as the person who has opened them has passed through. Double seat doors have necessarily a grooved guide on the bottom or threshold, which would be liable to get choked with dirt, unless it is kept covered or in some other way protected when the door is open. Fig. 7 shows an automatic cover as fitted to the vertical sliding door. In the horizontal sliding door (Fig. 8), the protection of the bottom groove is given by a tail filling piece carried by the shutter to fill the bottom groove when the door is open.

BUNKER WATER TIGHT DOORS.

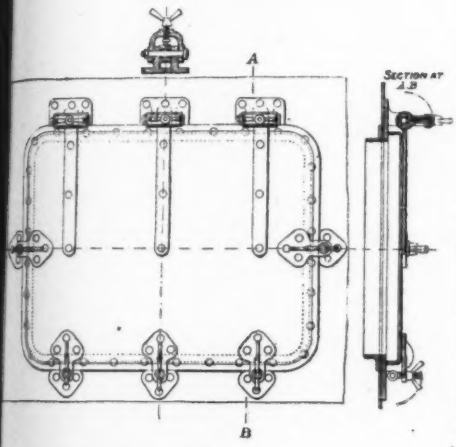
Bunker water tight doors are generally vertical sliding, single seated, screw-shaft geared, and close, as usual, downwards (Fig. 9).

These doors are generally acknowledged to be defective, on account of the coal that lies on their threshold when open, and which opposes an obstacle when the shutter is lowered to shut. Moreover, the pressure of the water inside the flooded bunker tends to open the door, which, therefore, is scarcely water tight, specially at the bottom, where there are no wedges or guides to keep the shutter well pressed against it. Both objections would, in my opinion, disappear if the door be made double seated and close upwards, as then it will always be self tight, whichever side of the bulkhead is flooded; and the coal that might lie on the threshold would fall down by itself, in the stokehold or in the bunker, when the shutter is being raised. From the working model (exhibited) of such a door, it will be seen that the door is double seated and closes upwards, the shutter, when the door is opened, being lodged in a box at the bottom, and filling with its upper edge the threshold groove. Nay, this upper edge forms the bottom of a frame cast solid with the shutter, and which fills the grooves of the door all round, and keeps them clear. Moreover, top and bottom of the door aperture are not straight, but convex, and the corresponding edges, both of frame and shutter, are made sharp, to facilitate the crushing and shearing of the coal, should any piece of it rest on the top edge of the rising shutter. The door is worked by the usual screw shaft gear, gearing in a nut fixed on top of shutter frame. Of course, any other gear might be fitted instead.

With the proposed arrangement, the threshold of the bunker door is higher than the bottom of the bunker by the whole height of the shutter; but by limiting the height of the door opening to two feet, which is sufficient, the said threshold, in ordinary cases, need not be more than a few inches above the boiler platform, as is usual at present.

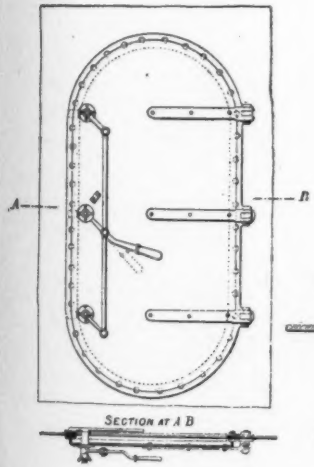
HINGED WATERTIGHT DOOR

FIG 1A



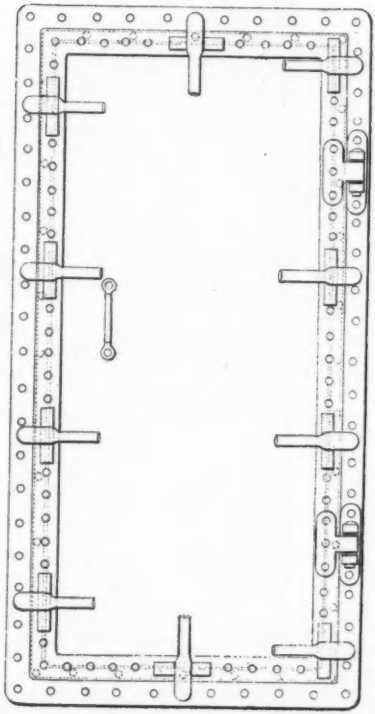
HINGED WATERTIGHT DOOR

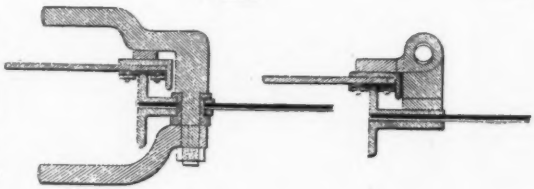
FIG 2A



HINGED WATERTIGHT DOOR

FIG 3A

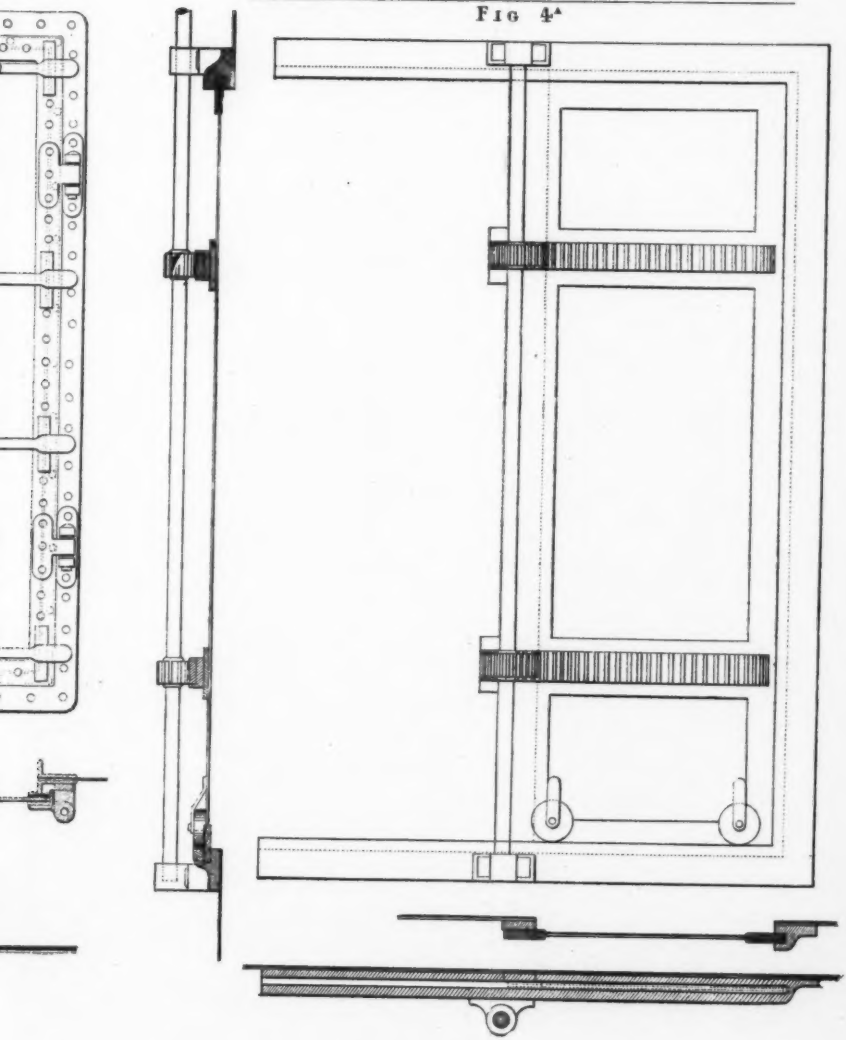




R

HORIZONTAL SLIDING WATERTIGHT DOOR SINGLE SEATED

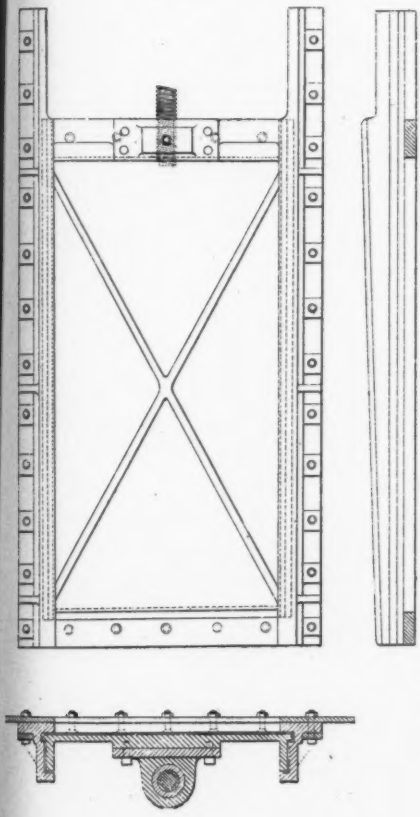
FIG 4A



Bunker Vertical Sliding Watertight Door

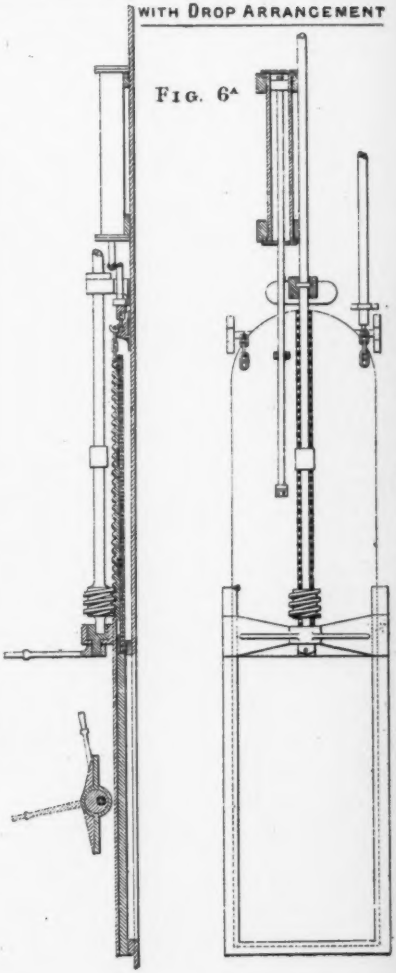
Single Seated

Fig 5A



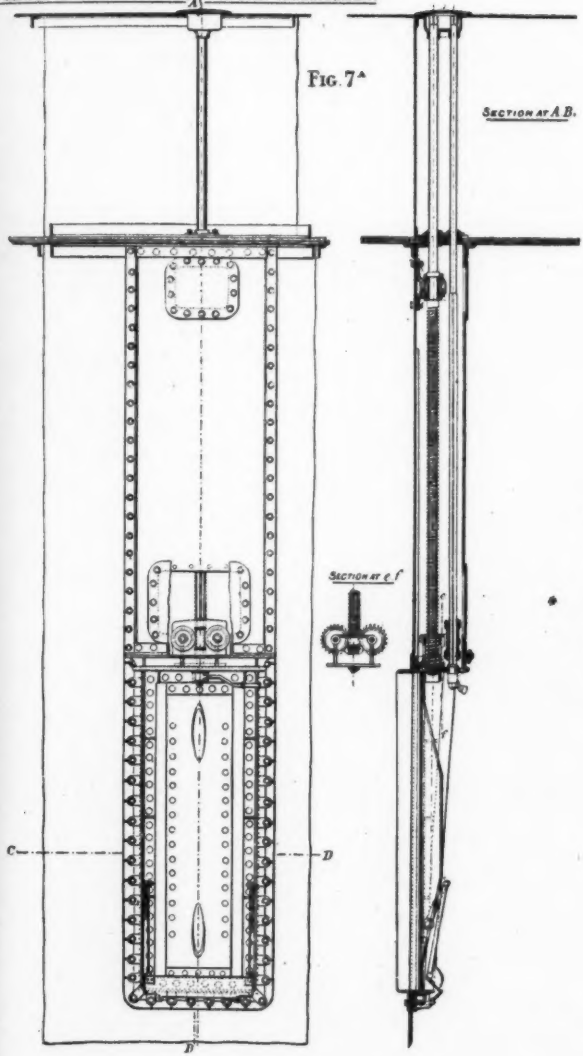
with Drop Arrangement

Fig. 6A

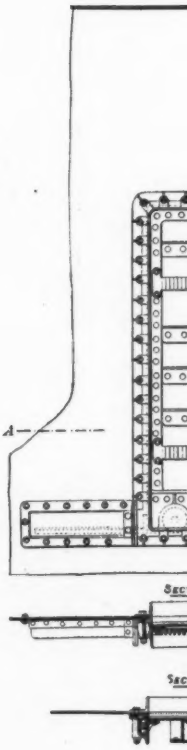


DOUBLE SEATED VERTICAL SLIDING DOOR WITH DROP ARRANGEMENT.

FIG. 7.

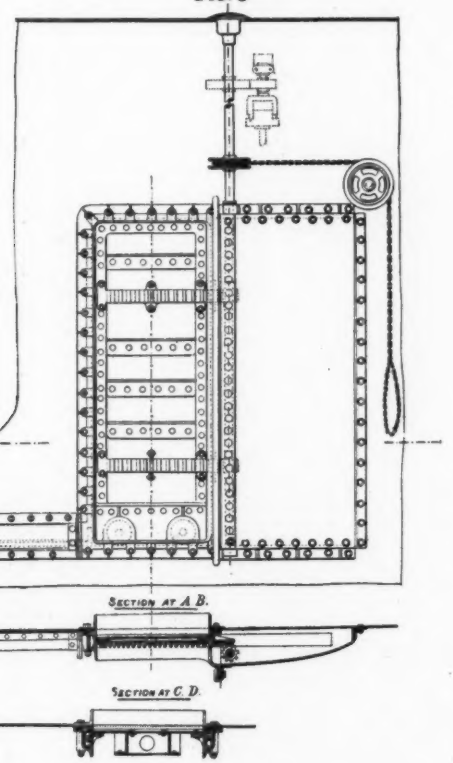


DOUBLE SEATED HORI



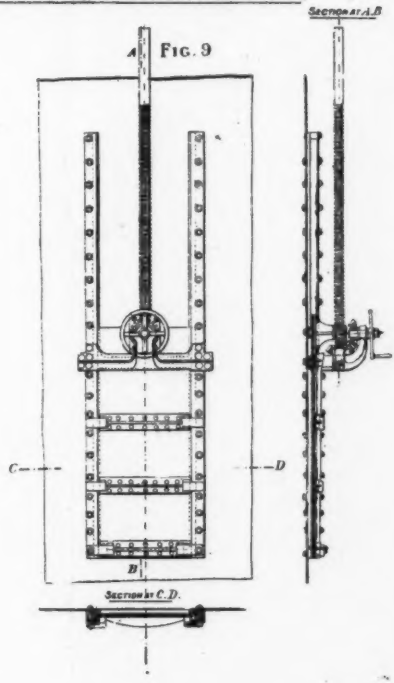
DOUBLE SEATED HORIZONTAL SLIDING WATERTIGHT DOOR

FIG. 8A



BUNKER SINGLE SEATED VERTICAL SLIDING WATERTIGHT DOOR.

FIG. 9



[Discussion on Water Tight Doors, from "Engineering."]

These two papers were taken together and the discussion was opened by **Admiral Wilson,** who said he had been captain of the sister ship to the unfortunate *Victoria* when that vessel was sunk, and, therefore, the question how to make ships of war safe had been forced upon his attention with double force. With regard to the effect of subdivision of ships in time of war, our vessels would be largely engaged in blockading the enemy's ports. If it could be so arranged that a ship would take one blow from a torpedo without the certainty of being sunk, an admiral would be more likely to take her in close to the enemy's port, because he would know that even if his ship were damaged, she might be got to dock and repaired in a comparatively short space of time. The naval officer and the naval architect alike would wish to do away with water tight doors if it were possible, but it was not. As at present arranged, the openings in bulkheads between engine rooms necessitated the going down of two or three steps and up again on the other side; he would alter this by raising the opening, so that it would be necessary to go up the steps first in passing through. It must be remembered that in cases of torpedo attack there would be generally no time to close water tight doors; torpedoes were mostly a weapon of surprise. There must be communication, however, between the parts of a ship, but it was a question whether it need be so ample as at present. He did not see any necessity for the engineer to go through doors to the magazines and various departments outside the machinery department, as in the *Sanspareil.* He believed the arrangements were better in the newer vessels. There was one reason why so many doors were necessary beneath the armored deck; if that deck had few hatchways they must burrow under it; that was the main danger, and accounted for the loss of the *Victoria.* It was necessary that the effect of filling compartments should be more considered, both in regard to trim and heel. He had made certain calculations with regard to the *Sanspareil;* one compartment would hold 1,000 tons of water; supposing there were no longitudinal bulkhead, filling this would bring

the ship down 2 feet; if a longitudinal bulkhead were fitted, the quantity of water admitted would be 500 tons; this would be on one side of the ship and the additional total immersion would be equal to an increased draught of 1 foot. The heel of the ship, however, would bring one side down 6½ feet below the original water line. He had made calculations with regard to filling bunkers. One of 100 tons placed on one side of the ship, if filled, would bring that side down 2 feet; this would be the same as if a whole compartment before referred to were filled. If, however, a similar bunker on the other side of the ship were put in communication with that first named, the ship would not heel, and the additional immersion below the water line would be but a few inches on each side. In the case of the *Victoria*, Sir William White had pointed out that in the compartments affected by the collision there was no longitudinal bulkhead; one of the principal compartments, however, was the foremost coal bunker of the starboard side. If this had communicated with the port bunker, so that both would have been filled, the ship would have been more immersed forward, but would not have heeled so much, and it was possible that under these circumstances, the battery door, through which water gained access, might have remained above water. In the *Sanspareil* they would be safer with all four boiler rooms full than with only one full. Speaking, generally, naval officers often ask for doors in bulkheads, without realizing what the effect of them would be in the case of flooding. A Russian officer had made an admirable suggestion to him, namely, that a scale model of a ship should be made, and that it should be filled with tin boxes representing the compartments; these should be removable, and by taking one out, so that water would be admitted in its place, the effect of flooding a compartment would be shown. This model should go with the ship on service, so that instruction might be given to all the officers.

Sir William White said that he indorsed the remarks of Admiral Wilson, but in speaking he was under some restraint. He could not criticise the work done by his colleagues in France, where he had been most hospitably given an opportunity of going

through the ships; neither could he follow those who commented on various war vessels for the construction of which he was responsible. He could only say generally, in regard to longitudinal bulkheads, that he agreed with the principles laid down by Admiral Wilson; it was, however, the practice of the Admiralty to thoroughly consider in all respects the effect of throwing open an important compartment to the sea. Regarding the proposed diminution in the number of water tight doors, Sir William could not remember whether there were 208 doors in the *Magnificent* or not; but allowing the figures to be right, Lord Charles Beresford proposed to do away with no more than nineteen of these. That was not a sweeping change. In connection with the design of the *Royal Sovereign* class they had asked opinions from naval officers as to how many water tight doors could be dispensed with, and only one had been suggested. A captain could close and lock any door he wished to, so that the naval officer had the remedy in his own hand if he found too many water tight doors. Lord Charles had said that a door weakens a bulkhead; this was not so, because there were compensations. It seemed to him that the meeting was now discussing a question that had been well thrashed out twenty years ago, after the loss of the *Vanguard*; then Sir Nathaniel Barnaby took the very action now recommended, that ships should be built with doors high up and communication between various compartments be abolished. Some vessels were constructed on these plans, but officers demanded that doors should be at lower levels; in fact, ships were sent to sea for years arranged on the plan suggested, and they were altered at the demand of naval officers. In an ideal ship, there would be no openings in bulkheads, but for practical purposes there must be doors. The problem to be solved was, how many, and this was one of the most serious questions that the naval officer and the naval architect had to face. As a fact, the doors, as now arranged, were placed in accordance with the naval officer's demands, so as to secure long distance steaming at high speeds, easy handling of ammunition, habitability and ventilation. In regard to 'tween deck doors there were occasions when men must pass through very quickly,

and he did not think that the proposed doors could be used for this purpose. Lord Charles had spoken of the inefficient manner in which doors were closed. This was, however, the human element with which the naval architect had manifestly not to deal. Lord Charles would place the collision bulkhead further aft, and would strengthen it. Our ships have two bulkheads forward, and this was considered better than one. In the *Camperdown's* collision with the *Victoria*, the collision bulkhead was effective. In another collision, the ship *König Wilhelm* was saved by a second bulkhead. The middle line bulkhead was said to be inefficient; the experience at the stranding of the *Howe* contradicted this. There the middle line bulkhead kept the water out of the boiler room, and the boilers were worked on one side, while the adjoining compartment was full.

Referring to the paper of Colonel Soliani, he did not propose to discuss the various forms of water tight doors illustrated and described; the contribution was an exceedingly valuable one, and he might say that Colonel Soliani only wrote it at his urgent request. The application of power to working doors had been suggested. This ultimately came to the scheme of the captain in the conning tower pressing a button and closing all doors; mechanically that could be done, but it had not been thought desirable on board a war vessel to increase the appliances necessary, but rather to trust to human means of carrying out the operations.

Admiral Fitzgerald was the next speaker. The tendency of his remarks was in opposition to the views of Lord Charles. Formerly it had been the naval officer who had asked for more doors, and he instanced his former ship, the *Collingwood*, in which doors had to be cut in bulkheads in order to get at the boilers. The door that Lord Charles had shown was not suitable for passing through, unless for very active and small persons. It was said that the convenience of the crew must be subordinated to the safety of the ship; that was true; but he would point out that the cumulative convenience of the crew made up the fighting efficiency of the ship.

Admiral Fremantle was surprised that the question of habitability had not been touched upon; the naval officer and the naval architect had been mentioned, but no one had thought of consulting the doctor. Credit was due to the author of the paper, who, though a naval officer, had risen superior to the prejudices of naval officers. He had referred to the incomplete manner in which water tight doors were sometimes closed when the operation was carried out in haste. Sir William White had looked on these remarks as a reflection on the officers and crew. When in command of the China station, he found that the doors were closed in a very short time, the drill being completed in 1½ minutes. He recognized that in competition things were often done more smartly and effectively, and he determined to test the matter, without saying anything previously to those engaged. When the word was given that all doors were closed, he sent down two officers, the engineer, who was not responsible for the matter, being one, to examine whether the doors were thoroughly secured. The report was very satisfactory. Sir William White had said that it was a matter for the captain of the ship whether the doors should be closed or not; he would point out, however, that it was often very difficult for the captain to do what he felt would be right. After the *Victoria* disaster, he had given orders that certain doors should be always kept closed, but pressure was put upon him; the doctor complained, and he had to give way. Whatever came, they must give ventilation to the ship. With regard to the bulkhead question, the Admiral gave the result of what he had seen during the late war in the East. Two ships were sunk, in one case it was generally supposed through gun fire, but the captain had flooded the magazine, and the vessel turned over as she sank; another ship was torpedoed, and she capsized in five minutes. He saw her bottom-up two days after. It seemed to him that in a man-of-war there was a strong tendency to capsize, and anything that could be done to prevent this was worth doing.

Admiral Colomb thought that naval officers would agree with a great deal that Lord Charles Beresford had said, their tendency

being to distrust the human element, upon which point they were the best judges. Lord Northbrook had had four or five conversations with the speaker in regard to bringing naval officers and naval architects into consultation in the initiatory stages of the design of a vessel, as it was so very difficult to alter plans when the work had proceeded far. The naval officer would make suggestions, but he would not know what would be the technical effect of his proposals in regard to those points which came solely within the province of a naval architect, such as stability, displacement, &c. In regard to openings in bulkheads, he would give an instance of their effect. In a ship he had commanded there was a sluice valve in the collision bulkhead; his predecessor had been very particular to keep this in working order, having the gear oiled and worked every day. He found that the only object was to drain the compartment; but if water were not admitted it was not necessary, whereas, if water did get into the forepart, the object of the collision bulkhead was to keep it there; he therefore had the sluice valve fastened up so that no one could open it.

Mr. Martell said that in mercantile vessels there were formerly sluice valves in collision bulkheads; these were often left open so that water got through, and Lloyd's, therefore, made a rule that no sluice valve should be in a collision bulkhead; they also stipulated that if sluice valves were placed in other bulkheads, the arrangement should be such that they were always accessible, whatever cargo might be on board; in any case, they discouraged them as much as possible. He would point out that the Admiralty were in a different position to Lloyd's. It was the duty of the latter body to make rules, and owners tried to do all they could to break them, or, rather, to bring pressure to bear in order to get a dispensation; the committee, therefore, had often to give way. The Admiralty officers had not this trouble, as they were their own designers, often their own builders, and owned the ships themselves. He sympathized with a great deal that Lord Charles had said. If they kept the main bulkheads intact the ship's safety would be insured, and would it not be worth

while to suffer some inconvenience to secure this end? In his position, he was squeezed, sat upon, and jumped upon, and he had to give way; but if he were the Admiralty he would never give way, and would have a large number of the existing doors closed. Where large steam pipes passed through bulkheads, it was often found impossible to keep the openings tight; he would therefore recommend that the pipes should be taken up and over the bulkhead, or, at any rate, high enough to be above water.

Mr. Seaton hoped to see Lord Charles' views carried out. The water tight door question was a very old one indeed. Sir William White had carried it back 20 years to the days of the *Vanguard*, but he would refer to a still more remote period in the history of the Royal Navy, when the *Royal George* was lost at Spithead, through water tight doors being open in order to secure ventilation, and that brought in the doctor question even then. These doors, of course, were in the side of the ship, being, in fact, the gun ports, through which the water came when the ship was careened. To judge from the discussion, the naval officer had the option of being either drowned or asphyxiated. Admiral Colomb had referred to a sluice valve in a bulkhead. He would give an instance illustrating this subject. In 1868, the extreme forward compartment of the *Black Prince* was tested for water tightness by being filled with water. There was no sluice valve in it; the dockyard people, therefore, did not quite see how they were to get the water out again, so they left it there, and the *Black Prince*, until the year 1890, actually went about with many tons of water in her forepeak. In fact, the admiralty only found out that the water was there by trying to make a sluice valve in the bulkhead. The onus of requiring these objectionable openings in bulkheads was largely laid upon the engineer, who was said to demand them in order that he might get about in his department. In ships the speaker had fitted for mercantile purposes, there was no communication between the engine room bulkheads, and they were found to act very well. He had an engine telegragh inscribed "Stop," "Easy," "Half speed," "Full speed," "More steam," and this was found to be sufficient for

practical purposes. Why could not the same thing be done in Her Majesty's Navy?

Professor Biles said that in the earliest iron battleships, bulkheads were made without doors, and openings were put in at the request of naval officers. The chief difficulty that appeared to face the ship designer in trying to keep bulkheads intact, was that the engineer demanded a line of communication fore and aft in his department, so that he could get from the engines to the boilers. He would propose the adoption of three screws; to each propeller he would have a set of engines and boilers complete in themselves, each set being placed in a separate transverse compartment. He thought that would be possible and would give effective subdivision. Though the triple screw arrangement would lead to a sacrifice of efficiency in propulsion, it might be worth while adopting it, as they would get more efficiency in the safety of the ship. While the armored deck existed, it was not possible to do away with piercing bulkheads unless the deck were pierced. He referred to certain Atlantic liners which he had designed, and which were without doors in the bulkheads. In that case, however, they were designed to be without doors, and all arrangements were made to meet this end. It must not be forgotten that the getting of coal to the stokehole from the bunkers accounted for a good many openings in divisions. He saw here a gentleman who had been chief engineer of one of the vessels he had referred to, and he hoped he would give his experience.

Mr. Gearing said that, in regard to what Professor Biles had just said, he had driven one of the ships across the Atlantic without doors in the bulkhead; in fact, he had been urged to have openings in the bulkheads, but had refused to accept them. The only thing he had to do was to make a proper arrangement of officers of the watch. He divided his engineer's staff into groups, and it was so arranged that when the officer in charge left the compartment there was no question who took up his duties. As an instance as how well this arrangement worked, he mentioned

that on one occasion out of eight feed pumps all had broken down excepting one. He was proud to say, however, that they had not stopped the ship, but had kept her going at 12 knots with only one 6-inch double acting feed pump. On another occasion the main feed pipe burst, but even then they did not stop the ship. Of course it was only by a good system of communication they had been able to do this, especially when they had only one feed pump for all their boilers; he took up his position at the voice tube, and received reports as the water was running low in the various boilers, and directed the feed accordingly.

Mr. Pilcher explained a door which he had devised and which would be automatically closed by the rush of water passing through an opening in the compartment. The door was a double one, or rather was two doors rigidly fixed together at an angle of 90°. Whichever way the water passed, therefore, it would tend to close one or other leaf of the door, supposing, of course, the rush was sufficiently rapid.

Lord Charles Beresford, in replying, said that the debates had thoroughly satisfied him that the water tight door question was one which ought to have been brought forward, and that the balance of opinion was on his side. Sir William White had said that out of 208 doors he, the speaker, only proposed to do away with 19. That sounded very few, but then these 19 were in the vital part of the ship. What had been said about captains shutting doors at will was all very well, but the fact remained that the doors were not shut, and the country had in consequence lost three millions of money, besides many valuable lives. As a plain matter of fact and experience, it was the doors being there that had lost the ships. It had been brought forward as an argument against him that the demand for more doors had come from his brother officers. That might be. All he could say was that he did not agree with them, and he thought the practical men were on his side. With regard to the small door high up in the compartment, although it might not be so convenient as existing doors, it was designed to be more convenient than going right up on deck over the bulkhead.

Reference had been made to the naval officer's influence in building ships. Each man had different views as to what was most essential for a warship; one wanted one thing and one another; it was very certain they could not all be satisfied, and some must give way. The question was, what was to be discarded? All the things asked for were doubtless valuable, but they could not all be included in a ship of anything like reasonable dimensions. When the *Royal Sovereign* was proposed, for the first time a reasonable course was adopted in designing a ship. Leading naval authorities were consulted, and Sir William White found that to meet their views he would have to make his ships 17,000 tons each. Some had to give way; the question was, who? and by talking the thing over in a business-like way, they had arrived at a compromise which had resulted in a good all-round ship. They might have attempted to reach this end by means of writing letters or minutes, but would never have succeeded. Since then our ships have been designed on sensible lines, and fairly represented naval opinion. Lord Charles concluded by referring to what he styled light ended ships. He said they would go down bottom up, and he did not believe in them. So strongly did he feel on this matter that he went out of his way to write to the Fleet Admiral, eighteen months before the *Victoria* disaster, pointing out the weakness of ships of this class. He had gone beyond his province in doing this, but he felt so strongly on the matter that he felt constrained to do so. What he had predicted eighteen months before, actually occurred when the *Victoria* was rammed by the *Camperdown*. He always distrusted light ended ships.

Colonel Soliani, in replying for his part of the discussion, said that he was well aware when he wrote his contribution that he was carrying coals to Newcastle, but he was supported by Sir William White, and was gratified by the manner in which his paper had been received. He quite agreed with Lord Charles that there should be as few doors as possible in bulkheads, and had views with regard to carrying out an arrangement by which this would be effected in the engine department. When the

engines are placed aft and the boilers forward of them, the engineer had to go all along to communicate. If, however, the engines were placed in the middle of the machinery space, with boilers fore and aft of them, short voice pipes or scuttles in the bulkhead would enable communication to be carried on. He would suggest, however, that a special officer should be placed in charge of water tight doors; he should be answerable for their efficiency, and see they were closed. In the ships of the Italian Navy there was a young naval architect who went to sea for instruction, and it was his duty to look after the water tight doors; this naval architect was thus brought in contact with naval officers when young, and he learnt their ways and the requirements of the ship.

NOTES ON STEAM SUPERHEATING.

By Mr. William H. Patchell, of London.

[Paper read before the Institution of Mechanical Engineers, January, 1896.]

Nature of Steam Superheating.—Superheated steam is steam of any pressure at a temperature higher than the temperature of its evaporation from water at that pressure. Saturated steam may be superheated by imparting additional heat to it at a constant pressure, during which process its volume increases. By permitting saturated steam of a given pressure to expand without doing work, superheated steam at a lower pressure may be formed. Steam cannot be superheated in the presence of the water from which it was evaporated, owing to the fact that the water takes up the heat and evaporates into further saturated steam. The corollary follows that water cannot exist in the presence of superheated steam; either the surplus heat in the steam will evaporate the water; or, if their be too little surplus heat to evaporate all the water, the steam will immediately become saturated by evaporating as much of the water as it can.

Messrs. Fairbairn and Tate, Hirn and Siemens, all found that saturated steam was not a true gas, and that its expansion on the application of further heat was at first much greater than that of a perfect gas. When a temperature of about 20 degrees Fahrenheit above that of the saturated steam was reached, the volume increased at about the same rate as that of a perfect gas. No data appear to be yet available as to the expansion of steam with high degrees of superheat; but there is little doubt that it would be that of a perfect gas. A marked feature in the use of superheated steam is the rapid fall in the superheat from radiation, &c. The reason of this more rapid fall in temperature, as compared with saturated steam, seems to be that the latter owes its heat retaining properties to the water spray carried in it. It is only

after this water spray has been evaporated that the steam becomes a true gas.

Aim of Superheating.—The greatest advantage to be gained by the use of superheated steam is in engine cylinders, and is due to the immediate absorption of the film of water on the metal surfaces by the surplus heat, thereby counteracting cylinder condensation, which is the heaviest loss in the expansive working of steam. In this connection, superheated steam would appear to have an advantage over steam jackets, inasmuch as the heat is applied exactly where it is wanted, and during the period that it is wanted, that is, up to the point of cut-off; whereas a steam jacket wastes a considerable part of its heat and time in warming up the exhaust.

Early Attempts at Superheating.—That economy attends the use of superheated steam in engine cylinders has been known at least since 1828, when Richard Trevithick reported on the engines at Binner Downs Mine in Cornwall.* The engineer of the mine, Capt. Gregor, wishing to rival the record of a neighboring mine where the cylinders had been cleaded in sawdust, built in his cylinders and steam pipes with brickwork, making a fire grate underneath them and flues around. The results were unexpected, and the duty of the engine was raised from 41 to 63 million foot-pounds per bushel (84 pounds) of coal. Trevithick tested the 70-inch cylinder engine, which, when five bushels of coal were burned in twenty-four hours under the cylinder, took 67 bushels under the boiler; when no coal was burned under the cylinder, 108 bushels of coal were used under the boiler for the same work, showing a saving of one-third of the coal by superheating. The steam pressure was 45 pounds per square inch, and the strokes, eight per minute. With the cylinder fires on, 13 gallons of injection condensing water were used per stroke, and heated from 70 degrees to 104 degrees; without the cylinder fires, 15½ gallons of condensing water were used per stroke, and heated from 70 degrees to 112 degrees. Trevithick followed this up by inventing in 1832 a tubular boiler, combined with a superheater between the boiler and the engine cylinder; he also jacketed the cylinder with the

* Life of Richard Trevithick, vol. 2, pages 315 and 323–4.

waste gases from the furnace. The arrangement consisted of an external series of vertical pipes, connected top and bottom to a hollow ring, which constituted the boiler; the superheating pipes inside it are formed like inverted siphons, so as to avoid jointing at the lower end next the fire. Trevithick had been combating cylinder condensation for thirty years before this date, having in 1802, in conjunction with Vivian, constructed a non-condensing engine, the cylinder of which was placed inside the boiler—a plan followed for many years with much success in agricultural portable engines by Messrs. Hornsby of Grantham.

Owing doubtless to the difficulty in controlling the temperature imparted to the steam, superheating made but little headway till 1850, when it came to the front again. Many plans were then proposed for superheaters and steam driers in various forms, both attached to boiler flues and separately fired. Asbestos packing and brass bushes with plumbago plugs were then introduced to meet the demand for steam tight glands under superheated steam.

More Recent Efforts.—Some results then obtained were reported to this institution by Mr. John Penn in 1859, followed by Mr. John N. Ryder in 1860. Mr. Penn described the apparatus employed by him in the Valetta steamer of the Peninsular and Oriental Company, with engines of 260 nominal horse power, where the saving in fuel due to superheating was 20 per cent. The superheater consisted of two horizontal faggots, each of forty-four 2-inch tubes, placed in the smoke box. The tubes were fixed into three wrought-iron boxes, welded up at the corners and closed with a flanged joint. The steam from the boiler passed into the center box, thence through the tubes into the end boxes on its way to the engines, taking up heat from the escaping gases which would have been otherwise wasted. The proportions of the apparatus are given by Mr. Penn as $2\frac{3}{4}$ square feet of superheating surface per nominal horse power; the boilers had a heating surface of 19 square feet per nominal horse power. The steam pressure was 20 pounds per square inch, and the amount of superheat about 100 degrees Fahrenheit.

Mr. John N. Ryder dealt with Messrs. Parson & Pilgrim's

apparatus as fitted on marine boilers, and also Mr. David Patridge's superheater. The Parson & Pilgrim apparatus consisted of two horse shoe pipes fixed over the fire grate in the internal flue of the boiler. Tests on the steamers *Osprey* and *Swift* showed a saving over saturated steam of 30 to 40 per cent. in fuel; and on H. M. steam tug *Bustler*, a mean of thirty-seven trials with a pressure of 8½ pounds and a temperature of 380 degrees in the cylinders, which is 144 degrees of superheat, gave 25 per cent. economy.

Mr. Patridge's apparatus was a cylinder filled with tubes, placed vertically in the uptake. The gases passed through the tubes, and the steam around them; the working temperature was from 360 degrees to 390 degrees. H. M. Steamship *Dee* was fitted and tested for several months by the Admiralty, when an economy of fuel of from 20 to 25 per cent. was obtained. An aggregate of about 5,000 horse power was stated to be then working with this apparatus.

Following closely on Mr. Ryder's paper was one read by the Hon. John Wethered, of the United States, at the Institution of Civil Engineers, in 1860, wherein he animadverted on the futility of the common kinds of superheater, and strongly advised mixed or combined steam, which he claimed to have introduced from America four years previously.

Reasons for Former Abandonment.—If superheating was so common and of such manifest importance and efficiency in the saving of fuel some forty years ago, the question arises, why was it given up, and what factors that led to its abandonment have been eliminated in modern practice?

Trouble was formerly experienced at the valve faces and in the cylinders from the decomposition and destruction, at the high temperatures of superheated steam, of the tallow and the low class lubricants then in vogue. This trouble was twofold: the cutting and excessive wear in the absence of lubrication, and the pitting caused by the fatty acids in the lubricant. On this score, however, no trouble need now be anticipated at any degree of superheat likely to be attained where good hydrocarbon oils are used. Gas engines run in regular working with a cylinder temperature

in the neighborhood of 2,000 degrees Fahrenheit, lubricated with good oil, and with ordinary care and attention instances of cutting are not frequent. The common use of metallic packings for glands and of piston valves in place of flat valves, has removed another serious obstacle. In this connection it will be well to note that pistons and valves, which show little leakage when used with saturated steam, may show considerable leakage with dry steam, probably owing to the film of water on the metal improving the fit when saturated steam is used.

Much of the trouble that has been attributed to the effects of superheat, in respect of cut cylinders and valve faces, has, in the author's opinion, been due in reality to the effect of alternate superheat and water in the steam, owing to want of proper control of the superheaters. A superheater may give a high degree of superheat when the fires are in good order, and at another time may even act as a condenser. The effect of this alternation demands much closer attention than it has at present received. A somewhat parallel case is the behavior of a good hydrocarbon cylinder oil, which in one engine with normal dry steam leaves no deposit; whereas in a sister engine, at the same steam pressure, with wet steam, a heavy deposit is formed from the same oil.

An instance of a cut cylinder which had to be rebored has lately come under the author's notice, where it appears from the evidence that the trouble is not to be attributed either to the degree of superheat in itself, or to the lubricant, or to neglect on the part of the engineer in charge, but to the alternate effects of superheated and wet steam in the cylinder.

The majority of the old troubles were met with in the engines, but the superheaters themselves do not appear to have been always above reproach. When endeavoring to trace failures to faults in pipes or joints, the author has sometimes found superheaters which were fixed with a by-pass for the steam, but none for the gases. The boilers were then worked occasionally with the steam shut off the superheater, and it is not surprising that the latter deteriorated rapidly, its position being eminently unsuitable for a combination of boxes, pipes and expanded tube joints.

Reintroduction of Superheating Apparatus.—Concurrently with the increased efficiencies gained in late years in both boilers and engines, competition has also increased, and with it has arisen the continual cry for cheaper power, cheaper transport, cheaper means of production. The result is that engineers cannot afford to dismiss without careful examination the claims of any plan, the adoption of which may diminish their consumption of fuel. It is this fact which has again brought superheating to the front, and has made it the subject of close inquiry in many quarters. Several kinds of superheaters are now in more or less extensive use, but only one of them is a radical departure from those of forty years ago. Any change in the others is rather in manufacture than in design, and their parentage can be traced by their strong family likeness.

TABLE I.—BOILER TESTS WITH AND WITHOUT GEHRE'S SUPERHEATER.

	With.	*Without.*
Total coal used during trial, pounds	1,550	1,940
water used during trial, pounds	15,400	15,100
Temperature of feed water, degrees Fahrenheit	205	201
Superheat in steam, degrees Fahrenheit	40	.....
Temperature of furnace gases before superheater, degrees Fahrenheit	600	600
Temperature of furnace gases after superheater, degrees Fahrenheit.	510	.....
Water evaporated per pound of coal, pounds	9 99	7.82
Water evaporated per square foot of heating surface per hour, pounds	2 23	2 20
Pressure of steam per square inch above atmosphere, pounds	110–114	110–114
More steam used, per cent	.....	5
Less coal used, per cent	34	.....
work on engine, per cent	.....	7

Gehre's Superheater.—This is in extensive use on the Continent and has been introduced into this country by Messrs. B. Donkin & Co., of Bermondsey. It consists of two drums filled with tubes, the steam entering the end of one drum, thence through a connecting pipe at the opposite end to the other drum and from the opposite end of this drum to the engine. These drums may be either fitted in the boiler flue or separately fired. Some of these superheaters have been fixed in England, but

unfortunately they have not been tested. Mr. Bryan Donkin kindly gave the author a copy of a test made in Germany of eight hours' duration on a water tube boiler with and without the superheater, Table I. The heating surface of the boiler was 861 square feet and of the superheater, 646 square feet. The superheater was placed directly behind the boiler in a special flue.

Hick, Hargreaves & Co.'s Superheater.—By the courtesy of the makers, the author has been favored with the following particulars and tests, Table II, of their superheating apparatus in a mill at Bolton. The apparatus consists of a nest of U tubes, bent to a large radius at the bottom, which are placed at the back of a Lancashire boiler where the hottest gases from the flues impinge upon them. The tubes are suspended from a tube plate, forming the bottom of a box, in which they are fixed by being expanded in the usual manner. The box is divided down the middle by a vertical diaphragm, so that the saturated steam entering at one side passes down and up through the tubes, and leaves superheated at the other side. A by-pass valve is arranged to regulate the flow of steam through the superheater, because only a portion of the steam from the boiler is intended to be superheated. Main valves are also provided, so that the superheater can be disconnected for examination, or even taken out entirely, without interrupting the working of the boiler. The Lancashire boiler to which the superheater is applied is 8½ feet in diameter and 30 feet long, with two flues of 3¼ feet diameter, having nine circulating tubes in each. The grate surface is 39 square feet; the heating surface in the boiler is 1,195 square feet, and in the superheater, 120 square feet. The area of passage through the superheating pipes is 22 square inches. The boiler pressure is 100 pounds per square inch above atmosphere. In the tests, a portion only of the steam was superheated. The steam pipes to and from the superheater are 3½ inches in diameter, and are provided with valves, which were kept full open. The main stop valve on the boiler is 8 inches in diameter, and was kept only $\frac{5}{16}$ inch open. The steam was taken to the superheater from underneath this valve, and the return pipe from the superheater

was conducted direct to the main range of steam pipe supplying the engine. The temperature of the gases was not taken. The engine is a horizontal tandem compound, fitted with Corliss valve gear; cylinders, $18\frac{1}{16}$ inches and $36\frac{1}{16}$ inches in diameter by 4 feet stroke. Each of the tests was $7\frac{1}{2}$ hours' duration.

TABLE II.—BOILER TESTS WITH AND WITHOUT HICK, HARGREAVES & CO.'S SUPERHEATER.

Dates of tests.	Number of tests with or without superheater.	Mean load.	Water evaporated per hour.	Coal burnt per hour.	Water evaporated per pound of coal.	Water evaporated per indicated horse power per hour.	Coal burnt per indicated horse power per hour.	Degrees of superheat.
1895.		*I.H.P.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*Deg. F.*
Feb. 19, 20	2 without	303.55	5,379.3	837.6	6.42	17.7	2.75	
Mar. 1, 2	2 with	290.50	4,706.3	667.2	7.06	16.2	2.29	42
" 5, 6, 7, 8	4 "	298.06	4,778.5	676.5	7.06	16.0	2.28	42
" 20, 21	2 "	311.20	5,141.1	734.7	7.00	15.5	2.35	55
" 26, 27	2 without	311.80	5,492.1	914.0	6.00	17.6	2.92	
Means	without	307.67	5,435 7	875.8	6.21	17.6	2.84	
	with	299.45	4,848.6	688.7	7.09	15 9	2.30	45.2

Economy in water per indicated horse power per hour, 9.6 per cent. with superheating.
Economy in coal per indicated horse power per hour, 19 per cent. with superheating.

The much easier working of the boiler for the same indicated horse power at the engine is to be noted. During the tests of March 20, 21, and March 26, 27, the load was practically identical. In the former tests with superheating, the rate of coal consumption was 18.8 pounds per square foot of grate per hour, whereas in the latter tests without superheating, the combustion went up to 23.4 pounds of coal per square foot of grate per hour. Where there is a low and uncertain chimney draft, this slower combustion alone would tend to much steadier and more economical steaming, and would more than counterbalance any obstruction in the flues caused by the superheating pipes, which appears to be more imaginary than real.

McPhail and Simpson's Superheater.—This apparatus is the invention of Mr. Hugh McPhail, and is manufactured in Wakefield by McPhail and Simpson's Dry Steam Patents Company.

It consists of two parts: the superheater proper and the steam generator of radiating tubes, which distinguishes it from all other plans. As applied to a Lancashire boiler, there are two nests of vertical steel tubes, expanded at top and bottom into cast-steel boxes, or "headers," as they are called in water tube boilers. These nests are placed preferably at the back end of the internal flues of the Lancashire boiler, in the downtake, where the furnace gases impinge on them and pass between them. One of the top boxes is connected to the usual anti-priming pipe in the boiler, and the corresponding bottom box is connected to a block, which passes into the bottom of the boiler, and from which a copper pipe runs along the bottom of the boiler under the internal flues to the front end and thence back again to the rear, where it passes out of the boiler and into the other bottom box. The second top box is connected to another copper pipe, which runs along the boiler over the internal flues, just below the water line, and ends at the main steam stop valve. The course of the steam is from the anti-priming pipe to the first top box, then down through the superheating tubes to the first bottom box, whence it enters the boiler, and passing through the lower copper pipe, gives up part of its superheat to the surrounding water before leaving the boiler and entering the second bottom box. It is then further superheated in passing up through the second nest of tubes; and thence passing through the second top box into the upper copper pipe in the boiler, it again parts with some of its superheat before finally leaving the boiler at the steam stop valve.

The complete apparatus thus consists of two external superheaters and two internal radiators, and the final degree of superheat depends upon the proportion of the superheating tubes to the radiating pipes. The function of these radiating pipes is most important, as they give off to the water in the boiler the superheat which might be dangerous in the engines at times of heavy firing; and, when the fires are green after cleaning, and the flue gases low in temperature, they prevent any possibility of the superheater becoming a condenser. They thus tend to keep regular the amount of superheat in the steam as it leaves the boiler. It will be evident, therefore, that this superheater may be arranged either for improving the evaporative efficiency of a

boiler, and at the same time giving dry steam at the engine, or for the steam to leave the boiler highly superheated.

In its complete form this superheater has been tested and fully reported upon by several engineers in this country, among whom may be mentioned Messrs. Crosland and Michael Longridge. In Tables III to V are given the results of some recent tests, one made by M. Armengaud at the works of Messrs. Isaac Holden & Son, Reims, and others at Kinleith and Thornliebank, for which the author is indebted to the manufacturers.

The Reims tests, Table III, were made before and after the apparatus was fixed on a Lancashire boiler 8½ feet in diameter and 28 feet long, with furnace tubes 3 feet 3¾ inches in diameter. The heating surface was 2,287½ square feet, and the grate area, 39 square feet. The steam was used exclusively for a simple Corliss condensing engine with cylinder 28 inches in diameter and 4½ feet stroke, running at 60 revolutions per minute, driving the machinery in a wool-combing mill. The work was arranged so that it should be as nearly as possible equal on the occasion of each test. Owing to an oversight during the test made before the superheater was fixed, the feed was left on while the boiler fires were being cleaned, the usual custom being to raise the water level before cleaning and then stop the pump. The result was a fall in the steam pressure from 78 pounds to 42½ pounds per square inch; and the boiler was so fully loaded that it took two hours to recover the normal pressure. The speed of the engine fell to 58 revolutions per minute, although the trips on the Corliss gear ceased to act and full steam was being taken for nearly an hour; 59 revolutions per minute were made for a further half hour before the usual speed was re-established. During the second test, the same procedure was intentionally repeated, in order that both tests might be exactly compared. The result was that the steam pressure fell only 3½ pounds and the speed was not affected at all. This difference is most striking, and is a forcible proof of the great increase in the capacity of a boiler when fitted with the superheating apparatus. The superheat was measured at the boiler stop valve, and was almost constant at 50 degrees Fahrenheit.

TABLE III.—BOILER TEST WITHOUT AND WITH McPHAIL AND SIMPSON'S SUPERHEATER AT MESSRS. ISAAC HOLDEN & SON'S WORKS, REIMS.

Lancashire boiler, 28 feet long and 8½ feet in diameter, with two internal flues, 3 feet 3¾ inches diameter; heating surface, 1,012 square feet; grate area, 39 square feet; supplying steam to a Corliss engine. Quality of fuel, Dourges.

Without or With Superheater.	*Without.*	*With.*
1. Date, 1894	June 20.	June 28.
2. Duration of trial, hours	7.83	8
3. Average boiler pressure per square inch above atmosphere, pounds	73.6	91.5
4. Temperature corresponding with pressure, degrees F.	318.7	331.6
5. Temperature of steam leaving boiler, degrees F	.....	381.1
6. Degrees of superheat, degrees F	.....	56.5
7. Average temperature of feed water, degrees F	117.5	119
8. Water evaporated, total during test, pounds	49,899	47,096
9. Water evaporated per hour, pounds	6,373	5,887
10. Water evaporated per hour per square foot of grate, pounds	163.4	151.0
11. Water evaporated per hour per square foot of heating surface, pounds	6.29	5.81
12. Coal burnt, total during test, pounds	7,364.7	5,435.3
13. Coal burnt per hour, pounds	941	679.4
14. Coal burnt per hour per square foot of grate, pounds	24.13	17.42
15. Ash and clinker, total pounds	937	613
16. Ash and clinker, percentage of coal, per cent	12.75	11.3
17. Combustible burnt, total pounds	6,427.7	4,822.3
18. Water evaporated per pound of coal, pounds	6 78	8 66
19. Water evaporated per pound of combustible, pounds	7.76	9.96
20. Average indicated horse power, I.H.P.	328 3	328.5
21. Coal per indicated horse power per hour, pounds	2.86	2.10
22. Water per indicated horse power per hour, pounds	19 41	18.19
23. Gain in coal per indicated horse power, per cent	.....	36.2
24. Gain in water per indicated horse power, per cent	.....	6.8
25. Gain in water evaporated per pound of coal, per cent.	.....	27.7
Equivalent Evaporation from and at 212 Degrees Fahrenheit. Superheat Neglected.		
26. Water per pound of coal, pounds	7 69	9.81
27. Water per pound of coal, gain per cent, pounds	.....	27.5
28. Water per pound of combustible, gain per cent., pounds,	8.80	11.05
29. Water per pound of combustible, gain per cent., pounds,	.....	25 5
Superheat Included.		
30. Water per pound of coal, pounds	7.69	10.07
31. Water per pound of coal, gain per cent., pounds	.....	30.9
32. Water per pound of combustible, pounds	8.80	11.35
33. Water per pound of combustible, gain per cent., pounds	.....	28.97

TABLE IV.—BOILER TESTS WITHOUT AND WITH McPHAIL AND SIMPSON'S SUPERHEATERS AT MESSRS. HENRY BRUCE AND SON'S, KINLEITH MILLS, CURRIE, MIDLOTHIAN.

Lancashire boilers, each 28 feet long and 7½ feet in diameter; heating surface, 920 square feet; grate area, 36 square feet. Quality of fuel, local Scotch coal.

Without or with Superheaters.	Without.				With.				Gain by Superheating.
1 Number of tests	1	2	3	Mean.	4	5	6	Mean.	%
2. Date of test 1895	July 2	July 3	July 4	.....	Nov. 28	Dec. 4.	Dec. 5		
3. Duration of test..hours	9	9.16	9	.....	8.75	9	9		
4. Number of boilers under test	6	6	6	.....	5	5	5		
5. Average boiler pressure per square inch above atmosphere....pounds	73.6	78	77.4	76.3	82	84.3	84.5	83.6	
6. Temperature corresponding to pressure	319	322.5	321.9	.....	325	327.9	327.5		
7. Temperature of steam leaving boilers	.....	.....	.....	.....	413	421	426		
8. Degrees of superheat	.....	.....	.....	.....	88	93.1	98.5	93.2	
9. Average temperature of feed water	116	124	118	.....	112	106	106		
10. Water evaporated, total during test	393,095	345,581	371,640	.....	392,410	420,867	413,375		
11. Water evaporated per hour per boiler	7,280	6,399	6,882	6,853	8,969	9,351	9,186	9,168.6	33.8
12. Water evaporated per hour per sq. ft. G.S.	202	178	191	.....	249	259	255		
13. Water evaporated per hour per sq. ft. H.S.	7.92	6.96	7.44	7.44	11.70	12.18	11.94	11.94	
14. Coal burnt, total during test	57,792	53,256	56,817	.....	47,452	49,423	47,544		
15. Coal burnt per hour per boiler	1,067	909	1,052	.....	1,084	1,098	1,056		
16. Coal burnt per hour per sq. ft. G.S.	29.7	26.9	29.2	.....	30.1	30.5	29.3		
17. Ash and clinker, total during test	7,071	6,741	7,479	.....	5,096	5,520	5,024		
18. Ash and clinker, percentage of coal	12.23	12.65	13.16	.....	10.73	11.16	11.81		
19. Combustible burnt, total	50,721	46,515	49,338	.....	42,356	43,903	42,520		
20. Water evaporated per pound of coal	6.802	6.489	6.541	6.611	8.269	8.515	8.694	8.493	28.4
21. Water evaporated per pound of combustible	7.750	7.428	7.532	7.570	9.264	9.586	9.721	9.524	25.8
Equivalent Evaporation from and at 212 Degrees Fahrenheit.									
Superheat Neglected.									
22. Water per pound of coal	7.713	7.306	7.404	7.474	9.418	9.758	9.963	9.713	29.9
23. Water per pound of combustible	8.788	8.365	8.526	8.559	10.552	10.985	11.140	10.892	27.2
Superheat Included.									
24. Water per pound of coal	.....	.....	.....	.....	9.799	10.158	10.406	10.121	35.4
25. Water per pound of combustible	.....	.....	.....	8.559	10.978	11.436	11.636	11.350	32.6

NOTE.—All temperatures in degrees Fahrenheit; all weights in pounds.

TABLE V.—BOILER TESTS WITHOUT AND WITH McPHAIL AND SIMPSON'S SUPERHEATER, AT THE THORNLIEBANK COMPANY'S WORKS, NEAR GLASGOW.

Lancanshire boilers, Nos. 6 and 7, each 28 feet long and 8 feet in diameter; heating surface, 955 square feet; grate area, 39 square feet. Quality of fuel, Greenfield Virgin coal. No. 7 boiler had superheater attached. No. 7 boiler with superheater did 12.97 per cent. more work, or, in other words, the saving effected was 19.08 per cent. Lowry, being the regular fireman and acquainted with the boilers, obtained the best results.

	1		2		3		4		5		Gain by superheat.
Number of test											
Date of test	August 28, 1895.		August 29, 1895.		Sept. 5, 1895.		Sept. 6, 1895.		Sept. 10, 1895.		
Duration of test	8 hours.		8 hours.		8 hours.		8 hours.		8.66 hours.		
Fireman	Lowry.		Parker.		Hannah.		Lowry.		Parker.		
No. 6 boiler without, and No 7 boiler with, superheater	without.	with.	without.	with.	without.	with.	without.	with.	without.	with.	o/o
1. Average boiler pressure per sq. inch above atmosphere	72	72	72.5	72.5	57	57	58	58	63	63	
2. Temperature corresponding to pressure	317.8	317.8	318	318	304 8	304.8	305.7	305.7	310	310	
3. Temperature of steam leaving boiler	309.3	373	304	372	303.8	363.9	300.1	366.5	300	362	
4. Degrees of superheat	.....	55.2	.....	54	.....	59.1	.....	60.8	.....	52	
5. Average temperature of feed water	161	156	161.5	155	145.6	151.0	148 5	153	146	151	
6. Water evaporated, total during test	58,910	69,586	68,978	76,181	55,890	62,040	55,277	65,600	70,684	75,461	
7. Water evaporated, gain due to superheater, per cent	.....	18.1	.....	10.4	.....	11.0	.....	18.6	.....	6 75	12.97
8. Water evaporated per hour	7,363	8,698	8,622	9,522	6,986.2	7,754.7	6,909.6	8,200	8,162	8,713	
9. Water evaporated per hour per square foot of grate	188.8	223.0	221.1	244.2	179.1	198.8	177.2	210.3	209 3	223.4	
10 Water evaporated per hour per square ft. of heating surface	7.71	9.10	9.02	9 97	7.31	8 12	7.23	8 58	8.57	9.12	
11. Coal burnt, total during test	9,632	9,632	10,976	11,200	9,086	9,171	9,408	9,408	10,752	10,304	
12. Coal burnt per hour	1,204	1,204	1,372	1,400	1,135 7	1,146.4	1,176	1,176	1,241	1,189	
13. Coal burnt per square foot of grate	30.4	30.4	34.3	35.0	28.4	28.6	29.4	29.4	31.0	29.7	
14. Ash and clinker, total	1,397	1,596	1,364	1,572	1,252	1,486	1,428	1,521	1,276	1,292	
15. Ash and clinker, percentage of coal	14.5	16.5	12.4	14.0	13.7	16.2	15.1	16.1	11.8	12.5	
16. Combustible burnt, total	8,235	8,036	9,612	9,628	7,834	7,685	7,980	7,887	9,476	9,012	
17. Water evaporated per pound of coal	6.11	7.22	6.28	6.80	6.15	6.76	5.87	6 97	6.57	7.32	
18 Water evaporated per pound of combustible	7.15	8.65	7.17	7.91	7.13	8.07	6.92	8.31	7.45	8.37	
Equivalent Evaporation from and at 212 Deg. Fahr.											
Superheat Neglected											
19. Water per pound of coal	6.63	7.88	6 81	7.42	6.69	7.38	6.42	7.59	7.22	8.00	
20. Water per pound combustible	7.76	9.44	7.77	8.64	7.82	8 81	7.57	9.05	8.18	9.15	
21. Gain due to superheater (on combustible) per cent	.....	21.64	.....	11.2	.....	12.6	.....	19.5	.....	11.8	15 35
Superheat Included.											
22. Water per pound of coal	6.63	8.12	6 81	7.70	6.69	7.59	6.42	7.84	7.22	8.24	
23. Water per pound of combustible	7.76	9.72	7.77	9 00	7.82	9.06	7.57	9.34	8.18	9.42	
24. Gain due to superheater (on combustible per cent	.....	25.25	.....	15.83	.....	15.85	.....	23 38	.....	15.16	19.08

NOTE.—All temperatures in degrees Fahrenheit; all weights in pounds.

At Messrs. Henry Bruce & Sons, Kinleith Mills, Currie, Midlothian, five Lancashire boilers are fitted with McPhail's apparatus. Their principal dimensions are 28 feet long by $7\frac{1}{2}$ feet in diameter; heating surface, 920 square feet; grate area, 36 square feet; working pressure, about 90 pounds absolute per square inch. In Table IV is shown a test of the complete range of boilers, six without the superheaters against the five fitted with them.

At the works of the Thornliebank Company, Glasgow, a Lancashire boiler is fitted with McPhail's apparatus. Its dimensions are 28 feet long and 8 feet in diameter; heating surface, 955 square feet; grate area, 39 square feet. One of their other boilers was tested against that fitted with the superheater, as shown in Table V. The superheat of the steam, leaving the stop valve of the boiler fitted with the superheater, averaged 56.2 degrees Fahrenheit. Since these tests, a second boiler has been fitted with the same apparatus, producing steam at 80 pounds per square inch above atmosphere and at 558 degrees Fahrenheit, being a superheat of 234 degrees Fahrenheit.

This type of superheater was adopted by the author in 1893 at the Maiden Lane station of the Charing Cross and Strand Electricity Supply Corporation, but had to be considerably modified to suit the Babcock and Wilcox water tube boiler, as it was found possible to put only one set of superheating tubes in the limited space between the top of the water tubes and the underside of the drum, and only one set of radiating pipes in the drum, so that the arrangement represents only one-half of the complete apparatus as applied to a Lancashire or double-flued boiler. The saturated steam is taken from the anti-priming pipe to the upper box of the superheater, whence it passes down through the superheating tubes to the lower box, thence up into the radiating pipes in the drum, and through these to the steam stop valve. The principal dimensions of the Babcock and Wilcox boiler are: $9 \times 9 = 81$ tubes, 18 feet long and 4 inches in diameter; total heating surface, about 1,827 square feet; drum, $23\frac{1}{2}$ feet long and 4 feet in diameter; width of fire grate, 5 feet 6 inches; total grate surface, 34.4 square feet. The principal dimensions of the superheater are: 75 superheating tubes of 1 inch diameter, heat-

ing surface, 355 square feet; 12 radiating pipes of 2 inches diameter, heating surface, 174 square feet; area through superheating tubes, 58.9 square inches; through radiating pipes, 37.7 square inches, and through steam stop valve, 28.27 square inches.

Complete tests of one boiler were made by Professor Kennedy before and after the superheating apparatus was fixed, and the principal results are given in Table VI. The dynamos are Edison-Hopkinson continuous-current, shunt-wound, driven by Willans engines.

TABLE VI.—BOILER TESTS WITHOUT AND WITH McPHAIL AND SIMPSON'S SUPERHEATER.

	Without.	*With.*
1. Date of trial, 1893	June 20.	October 17.
2. Duration of trial, hours and minutes	8.15	8.31
3. Indicated horse power of engines working at full load, I.H.P.	135	135 + 80
4. Full output of dynamos, amperes × volts	$750a \times 105v$	$\begin{cases} 750a \times 105v \\ 450a \times 105v \end{cases}$
5. Coal burnt, total pounds	3,229	4,528
6. Coal burnt per hour, pounds	389	532
7. Water pumped into boiler, total pounds	28,000	43.655
8. Water pumped into boiler per hour, pounds	3.457	5,125
9. Mean electrical horse power, E.H.P.	82.15	129.2
10. Total kilowatt hours (units)	686.4	824.2
11. Mean kilowatts	61.3	97.0
12. Boiler pressure above atmosphere, per square inch, pounds	131 3	140 3
13. Mean temperature of steam on leaving boiler, degrees Fahrenheit	355	377.1
14. Mean temperature of saturation at boiler pressure, degrees Fahrenheit	355	361.0
15. Mean temperature of steam in engine room steam pipes, degrees Fahrenheit	.....	365.1
16. Mean temperature of saturation at probable pressure in engine room steam pipes, degrees Fahrenheit	.....	358.3
17. Mean temperature of feed water, degrees Fahrenheit	80.4	79.76
18. Calorific value of 1 pound of coal, Th. U.	14,840	14,790
19. Equivalent evaporation per pound of coal, pounds	15.36	15 31
20. Carbon value of coal per pound, pounds	1.023	1.020
21. Actual water evaporated per pound of coal, pounds	8.89	9.65
22. Evaporation per pound of coal from and at 212 degrees, pounds	10.50	11.47
23. Evaporation per pound of carbon value, pounds	10.30	11.22

	Without.	*With.*
24. Coal burnt per hour per square foot of grate, pounds...	11.3	15.5
25. Coal burnt per hour per electrical horse power, pounds..	4.74	4.12
26. Water per hour per electrical horse power, pounds.....	42.1	39.7
27. Coal per kilowatt hour, pounds.....	6.35	5.5
28. Water per kilowatt hour, pounds.....	56.4	52.8
29. Efficiency of boiler, 100 × line 22 ÷ line 19, per cent..	68.4	74.9
30. Temperature of gases leaving boiler, degrees Fahrenheit.....	309	376
31. Mean chimney draft, inch of water, inch.....	0.3	0.4

The great increase in the capacity of the boiler will be noted in line 8; the steaming was much easier and steadier, and, at the same time, the efficiency of the boiler improved from 68.4 per cent. to 74.9 per cent. (line 29), and this with cold feed. Practically the whole of the superheat was lost in the range of steam pipes between the boiler and engine. The slight difference in water used per kilowatt hour may be accounted for by the engine not being in such good order in the second test as in the first. It had been thoroughly overhauled immediately before the June trial, and had been in daily use from that date until the October trial, so that both valve and piston rings would be somewhat slacker in October than in June. The same cause would affect the coal consumption, which nevertheless shows a saving of 13.5 per cent.

The increased capacity and ease in working of the boiler have been as marked in its subsequent use with the superheating apparatus; in regular work it is evaporating about 50 per cent. more than heretofore. At first the author had some misgivings as to incrustation forming in the superheating tubes from the priming water, but from examining them closely on several occasions after a run of 4,000 hours and more, and finding them perfectly clean, he is satisfied on this point. The top box, by its increase in area over the steam pipe, gives a period of comparative rest in the flow of the steam, and acts as an efficient separator for the water or scum carried over. A steam trap fitted to the box discharges any such accumulation regularly, thus preventing its being carried into the superheating tubes. The bottom box is also fitted with a trap to intercept any leakage from the steam stop valve when the boiler is shut in.

The first apparatus proved so satisfactory that a second was applied to the companion boiler in 1894, when the effect of the superheated steam in the pipes began to be marked by a decrease in the discharge from the drains and in the leakage from joints. There are altogether seven boilers, of which five or six are in general use on a common steam main. The figures in table VII show this effect clearly.

TABLE VII.—STEAM TESTS WITHOUT AND WITH McPHAIL AND SIMPSON'S SUPERHEATERS.

Without and with superheaters.	Without.		With.		
Boiler pressure, absolute, pounds per square inch	166	168	157	162	162
Corresponding temperature of saturated steam, Fahrenheit	366.5	367 0	362 0	364.5	364.5
Temperature in main steam pipe in engine room, Fahrenheit	359	361	371	375	373
Fall or rise in temperature of steam, degrees Fahrenheit	−7.5	−6 0	+9.0	+10 5	+8.5

Induced Draft.—The duty of the boilers having been increased to the above extent and the priming difficulty being quite overcome, the only limit to the evaporation was the chimney draft. As the two boilers were fitted with an independent flue and chimney, they lent themselves readily to an experiment in this direction. Having considered several schemes of forced and induced draft as an auxiliary, the author finally decided on putting a fan in the flue at the back of the boilers. As there was no space available for any form of economiser between the boilers and the fan, no attempt could be made to diminish the loss from heat in the waste gases. The gain sought for was in the direction of increasing the capacity of the existing boilers, so as to render steaming independent of the natural effects of foggy or heavy weather, and by working the boilers at a higher rate to diminish the proportion of radiation losses, which are practically constant to all loads.

The fan selected is a 72-inch single inlet, made by Messrs. G. E. Belliss & Co., and driven direct by one of their tandem com-

pound self-lubricating engines, having cylinders 3½ inches and 6 inches in diameter and 4½ inches stroke, working at 150 pounds boiler pressure, and running at 300 revolutions per minute. The engine and fan were put in somewhat large for the estimated work, in order to secure slow speed and quiet running, with the result that within a few feet of the fan it is impossible to tell by the sound whether it is running or not; this is a marked improvement on many fan engines. A draft in the flue at the fan inlet equal to a 2-inch water gauge has been easily maintained. The usual method of working is to work the boilers on natural draft at times of light load; and then, as the load increases, to start the fan, close the by-pass in the flue, and work steadily at 1 inch water gauge. With this draft the superheater tubes are continually bathed in incandescent gases, but not the slightest trouble has been experienced with them. In order to test the thorough reliability of the tubes, and in view of the fact that trouble was most likely to arise, if at all, when getting up steam, one of the boilers was shut in, and the steam let down day after day for some weeks and then raised again with the induced draft, and there was an entire absence of any signs of irregularity or trouble.

When the boiler is steaming freely, an iron bar inserted through the brickwork to a point near the ends of the tubes soon becomes red hot; and the temperature as taken by a platinum coil pyrometer at this point is about 900° Fahrenheit. At this temperature it appears to be of little importance whether the cooling agent is water or steam, so long as the circulation is kept up. This circumstance is most interesting in view of Mr. Durston's Devonport experiments, reported in his presidential address to the Institute of Marine Engineers,* as to the permissible limit of temperature in a tube or tube plate, which he places at about 750° Fahrenheit; and in view also of the grave doubts that are frequently expressed as to the safety of steel tubes exposed to furnace temperatures, without a perfect circulation of water on the other side of the metal. What temperature the tubes actually reach the author is unable to state, but the steam

* See page 780, Vol. VII, of the JOURNAL.

coming out of them is over 600° Fahrenheit. The tube plates would be lower in temperature than the outer ends of the tubes, because the gases are drawn downwards and away from the plates by the draft. No trace of leakage at any one of the tube ends has yet appeared.

A further test of the boiler with the induced draft was made on January 2, 1896. It was not possible to shut off part of the steam ring main and to use the steam on certain steam dynamos only, measuring the electrical output from them, as had been done in the two former tests; an evaporative test only was, therefore, arranged for. The stop valve temperature was measured about 5 feet from the stop valve at the boiler on a branch pipe about 10 feet long, connecting the boiler with the main ring. A mercury thermometer in a mercury cup let into the steam pipe was used in this position. Being anxious to get the temperature of the steam between the superheater and the radiating pipes in the drum, the author had tried mercury thermometers, which failed. The difficulties due to the high pressure and temperature were successfully overcome, however, by Mr. F. W. Burstall, to whose ingenuity and kindness in co-operation the author is indebted in this matter. With a temperature of 1058° around the superheating tubes, steam entering at 362° left them at 650°, and after passing through the radiating pipes in the drum, left the boiler at 403° Fahrenheit. The principal results are given in Table VIII, the boiler being fired with Welsh steam coal. It will be noted that the application of the superheater, together with a stronger draft, has increased the capacity of the boiler by 140 per cent., or raised the evaporation from 3,457 pounds per hour (Table VI) to 8,293 pounds without increasing the space occupied, which is a most important gain, and a saving both in capital and in rent. In comparing the temperature here given of the gases leaving the boiler with those given in Table VI, it should be noted that in Table VIII the temperatures were taken between the back tubes and the wall in which is situated the damper communicating with the flue. In Table VI, the temperatures were taken in the flue, where the gases are cooled by the

influx of cold air through the damper slots and by any leakage through the other boiler, which was shut off at the time.

TABLE VIII.—TEST OF BABCOCK AND WILCOX BOILER FITTED WITH McPHAIL AND SIMPSON'S SUPERHEATER.

Date of trial	January 2, 1896.
Duration of trial	8 hours.
Coal burnt, total, pounds	8,050
per hour, pounds	1,006.25
Ash and clinker, dry, pounds	476
Water evaporated, total, pounds	66,350
per hour, pounds	8,293.75
Boiler pressure above atmosphere, per square inch, pounds	148.3
Temperature corresponding to pressure, degrees Fahrenheit	365
Mean temperature of steam at stop valve, degrees Fahrenheit	396.9
Degrees of superheat, degrees Fahrenheit	31.6
Mean temperature of feed water, degrees Fahrenheit	48
Actual water evaporated per pound of coal, pounds	8.24
combustible, pounds	8.76
Water evaporated per pound of coal from and at 212° Fahrenheit, pounds	10.16
combustible from and at 212° Fahrenheit, pounds	10.80
Coal burnt per square foot of grate per hour, pounds	29.3
Water evaporated per square foot of heating surface per hour, pounds	4.37
Temperature of gases leaving boiler, degrees Fahrenheit	655
Mean chimney draft, inches of water	1.11

Schwoerer's Superheater.—This superheater is the invention of Mr. Emile Schwoerer, of Colmar, Alsace, who was for some time private secretary to the late Mr. G. A. Hirn. It was Mr. Hirn who first took up superheating seriously, and it is due to his energy that so much has been done with it in practical working in Alsace. Mr. Schwoerer's improvements were in the direction of reducing the space occupied by the apparatus, and he attained this end by employing a coil of pipes with gills on them both inside and outside, thus getting large surfaces in a small bulk. Regulation of the superheat by deflecting the hot gases away from the tubes, rather than by varying the proportion of the total steam passing through the tubes, is due to Mr. Schwoerer, though this regulation does not appear to have been generally carried out. By the courtesy of Prof. W. Cawthorne Unwin, the author is enabled to give the tests in Table IX of Schwoerer

TABLE IX.—BOILER TESTS WITHOUT AND WITH SCHWOERER'S SUPERHEATERS

Tests made by	Mr. Walther Meunier.								Professor Unwin.			
Number of test	1	2	3	4	5	6	7	8	9	10	11	12
Without or with superheaters	Without	With	Without	With	Without	With	Without	With	Without	With	With	With
Number of boilers in use	3	2	4	3	4	3	1	1	4	3	3	3
Duration of trial, hours and minutes	11.10	11.0	10.24	10.19	11.30	11.30	11.30	11.30	6.0	5.0	6.0	5.0
Mean indicated horse power	278	276	554	564	310	309	116	119	475	491	501.4	502.3
Steam per indicated horse power, per hour, pounds	19.8	17.1	21.87	17.44	19.00	15.70	21.6	19.2	19.75	15.63	17.06	15.61
Coal per indicated horse power, per hour, pounds	3.16	2.37	3.78	3.01	2.98	2.38	3.45	2.64	3.15	2.59	2.56	2.51
Boiler pressure above atmosphere, per square inch, pounds	...	...	86.7	86.7	68	65	...	...	95.72	99.05	93.74	94.00
Degrees of superheat Fahrenheit at valve chest	...	115	...	102	...	118	...	...	...	118.3	119.2	126.9
Economy in coal, per cent.	...	25	...	20	...	20.7	...	23.5	...	17.6	18.5	20.1
" " steam, per cent	...	14	...	20	...	17.4	...	11.0	...	20.9	13.6	20.9

superheaters in Alsace, some of which were carried out by himself, and others by Mr. Walther Meunier, Engineer-in-chief of the Alsatian Association of Steam Users. It will be noted that in tests 1, 3, 5, 9, one more boiler was required to do the work when saturated steam was being used at the engine. The boilers were of the elephant kind, with Green's economisers.

An application of the Schwoerer superheater has been made by Messrs. James Simpson & Co. to a Babcock and Wilcox water tube boiler at the Grand Junction Water Works, Kew. The boiler is of the same size as those fitted by the author with McPhail's apparatus at Maiden Lane. Full details of the trials unfortunately cannot be obtained, but the saving effected is satisfactory. Tests were conducted by Mr. Osbert Chadwick before and after the superheater was fixed, with the following results—Table X:

TABLE X.—BOILER TESTS WITHOUT AND WITH SCHWOERER'S SUPERHEATER.

Date..	Jan. 21, 1893	Dec. 20, 1893	Feb. 22, 1894	Mar. 13, 1894
Degrees of superheat, degrees Fahrenheit,	0	57.7	109.5	57
Steam per pump horse power, per hour, pounds	20.98	19.71	18 75	19.48
Saving effected, per cent	...	6,05	10.63	6 75

A test was also conducted by Mr. Goodman, the superintending engineer at the pumping station, under ordinary working conditions, from December 8, 1894, to January 5, 1895, the engine and boiler being kept continually at work. The fuel used was 86.98 per cent. anthracite peas, and 13.02 per cent. breeze, the draft being assisted by a Meldrum blower. The results thus obtained were:

Duration of trial, hours	723½
Feed water per hour, pounds	3,223
Fuel per hour, pounds	471
Steam per pump horse-power per hour, pounds	17.74
Fuel per pump horse-power per hour, pounds	2.58
Mean superheat, degrees Fahrenheit	121

These results showed a saving of about 15 per cent. on what had been obtained before the Schwoerer superheater was fixed.

This type of superheater is also made by Messrs. Fraser and Chalmers, Erith, who have one in constant use at their works.

Sinclair's Superheater.—Another form of superheater is due to Mr. George Sinclair, of Leith. There is here a departure from the usual method of securing the tubes, which in this apparatus are flanged and bolted to the cross inlet and outlet pipes, instead of being expanded into them. In such positions, an expanded joint is generally considered desirable; but here the joints are removed from the action of the hot gases, and a bolted joint gives much greater facilities for removing a tube in order to examine or clean it. In conjunction with a marine dry back boiler, as fitted by Professor Kennedy at the Edinburgh Electric Lighting Station, the arrangement is very compact, and should prove highly economical. The hot gases from the smoke box at the front are led to the back over the top of the boiler, passing among the superheating tubes, thence down the sides of the boiler to the center fluc underneath it. The apparatus was described in Mr. Burstall's paper, read at the last meeting (October, 1895), and in the discussion, Professor Kennedy stated that further tests were then in hand; the author would be very glad if the present should be considered a convenient opportunity for publishing the results of them.

It is much to be regretted that so little has been done as yet with superheated steam at the engine. In nearly every instance the superheat appears to be gone, if not at the steam chest, at any rate immediately on admission to the cylinder. But even under these circumstances, the advantage of superheating is manifest from many of the tests given above; and it must be recognized that, although the steam may be cooled down again to the temperature corresponding to the pressure, it is still dry steam, and is a better working gas than the saturated solution of water dust supplied by an ordinary boiler. The desirable amount of superheat has been generally considered to be the equivalent of the heat lost by initial condensation; but this does not obtain in practice. The amount of heat lost in initial condensation is

generally from 20 to 25 per cent. of the total heat of the steam above boiling point. Tests with superheated steam show a saving of 20 per cent. with only 5 per cent. extra heat in the steam. This point has been brought out clearly by Mr. W. H. Booth in his paper on cylinder condensation, read to the Manchester Association of Engineers a few months ago, wherein it was shown that the amount of superheat is but little in excess of that necessary to supply the heat required for making good the latent heat which disappears as work during expansion.

When preparing to respond to the request that he would contribute a paper giving his own experience with superheating, the author found that, although a great deal had been done, but little information on this subject was to be met with in the Institution Proceedings. He has therefore endeavored, to the best of his ability, during a particularly busy winter, to fill up the blank by collecting and recording all the data that he is himself possessed of. It is not imagined that the superheaters here described make up a complete list; and it is hoped that any which have not been included in the paper will be dealt with to better advantage by speakers in the discussion. The theory and advantages of superheating at the engine have not been touched upon, not only for want of space, but also in the hope that some member of the Institution who has given the subject much attention may be tempted to contribute a comprehensive paper thereon. In conclusion the author desires to thank the several gentlemen and firms who have kindly given him information and plans.

THE BATTLE OF THE YALU AND ITS EFFECT ON THE CONSTRUCTION OF WARSHIPS.

By Mr. L. Ferrand, Génie Maritime of the French Navy.

[Abstract of a paper read before the Association Technique Maritime, 1896.]

All of the Chinese vessels had one fault in common; they were not sufficiently subdivided above the protective deck, which exposed them to capsizing, if any of them were struck near the water line. It is thus, according to all probability, that the *Chi-Yüen* sank. The great speeds, attained by several of these vessels on their trials, could no longer be reached on account of the bad condition of the propelling machinery. The armament was good enough, but very badly maintained. Finally the personnel, officers and men, wanted experience and training.

The Japanese, on the contrary, had built for themselves, with small resources, dockyards, and a navy commensurate with the power of their future enemy. They had armored vessels of small displacement, good speed, and an armament which was overwhelming compared to that of the enemy. Their fleet was manned by relatively well-trained men; the matériel, and particularly the machinery, was not in good condition, but fair speeds could still be obtained.

On the *Hashidaté*, a Fox furnace in one of the boilers had collapsed; during the whole war only five boilers could be used, the sixth and damaged one being used as a fresh water tank. The boilers of the *Itsukushima* were being retubed when war broke out. All the tubes on hand were too small; these had, therefore, to be put in with a ring on each end. By reducing the boiler pressure to 140 pounds per square inch, the ship was made serviceable and able to steam 13 knots, 16.54 being her trial speed. The *Fuso* had old boilers and could not steam much over 8 knots.

The heavy guns do not seem to have been, during peace, the objects of care or sufficient practice.

It will be useful to call attention to the necessity of devoting such resources to the maintenance of a fleet that, when war breaks out, a majority of the ships may not have lost the qualities of speed which were given to them at great cost. A Navy, desirous of not squandering millions, must so organize its navy yards that repairs, renewing of boilers, &c., can be done, even in time of peace, with the least possible delay. In this matter, the proverb "time is money" is particularly applicable.

The battle of the Yalu was above all a combat of guns in which the Japanese had an enormous advantage; 250 pieces against 185, and very much better arrangements of ammunition supply.

Neither side possessed shells containing high explosives, like melinite, roburite, &c.

It cannot be concluded, from the victory of the Japanese, that cruisers are superior to armored vessels. If the Chinese fleet had been composed of armored vessels like the *Chen-Yüen* and *Chin-Yüen*, if it had possessed as many guns and been manned as well as the Japanese, it would certainly have been victorious.

It is equally erroneous to say that the Japanese owed the victory to the superior speed of their vessels, for they did not make use of it; the Japanese fleet manœuvred at *seven* knots. The flying squadron, composed of cruisers that made over 19 knots on trial, did not exceed a speed of 12 knots. The Chinese fleet manœuvred at from 5 to 6 knots.

From the point of view of tactical formations, the battle of the Yalu has proven, above all, the superiority of order over disorder; of manœuvres in concert over haphazard, individual action at 7 knots.

An examination of the nature of the damage done during the battle presents useful subjects for reflection.

First, from the beginning of the fight, the Chinese vessels were on fire, their superstructures demolished, and their smoke pipes riddled; on the Japanese vessels, the same condition existed, although in a less degree. On the *Lai Yüen*, the protective deck and certain compartments became nearly red hot on account of

the fire, and the machinery compartments had to be abandoned. The explosive shells of the Japanese started fire wherever there was wood. The demolition of the superstructures was not as complete as was at first reported; the Japanese fired too high. On both sides the armored parts remained standing, but on the Chinese vessels everything on deck and in the cabins was destroyed.

Generally, shells exploding in the coal in bunkers or in the cellulose of the cofferdams did little damage. The protective decks effectively shielded the machinery; but, on account of the long range at which the battle was fought, and the low position of the guns, the shot could hardly reach these decks.

The projectiles did much damage among the men; every shell bursting in the vicinity of a group of men killed every one. This shows the absolute necessity of exposing the least possible number of men to the enemy's fire. This same fact condemns, without appeal, batteries containing several guns; the guns should be separated, unless they are on an open deck.

From the beginning of the battle, the Chinese had lost their signals, and the Japanese could not transmit orders on account of the noise. The ingenious contrivances which are constantly being increased on board ship are, therefore, of little use during an engagement.

Finally, the part played by torpedoes was absolutely nil.

The firing on both sides lacked precision. The Japanese did not know how to utilize their excellent matériel; the rapid fire guns of the *Itsukushima* fired, on an average, one shot every three minutes, and the Canet guns, one shot per hour. Consequently, the number of killed was very small, and the damage to the vessels hit not very great. The latter is shown by the fact that the *Ching-Yüen* and *Ting-Yüen* were repaired in 8 days, and the *Chen-Yüen* in 20 days. The Japanese vessels generally were repaired in 48 hours by the force on board. The *Matsushima*, *Hiyei* and *Akagi*, however, had to return to Japan, and were under repairs one month.

From the foregoing facts, the result may be drawn that if the Japanese ships had been manned by Europeans, the disaster

to the Chinese would have been sudden and complete; and it seems certain that, in future fights, the rapid fire artillery will promptly destroy the superstructures and set on fire everything combustible, while the heavy guns will demolish the vital parts not protected by armor.

If these results follow, it is evident that cruisers can no longer be expected to support battleships in action; their role will be radically different. They will serve as scouts, and as such, their chief requisites will be good sea-going qualities, speed and endurance; the protection will be reduced to a protective deck and complete subdivision; and the armament will consist of a few, light, rapid fire guns.

As regards the battle ship, the utility of which is open to discussion, if it is to be preserved, it must, first of all, have sufficient stability and buoyancy and satisfactory sea-going qualities; then a thick armor belt for the whole length; the principal machinery must be protected by an armored deck, the openings in which must be so arranged that pieces of projectiles can not enter. As these protective decks will not be sufficient over the engines and boilers, additional armor protection must be given in the central part of the vessel. A cellular belt at the level of the water line will complete the protection. The armament, very powerful, should consist of heavy guns in closed turrets, firing rapidly, seconded by guns of medium caliber, in turrets or armored redoubts, each gun separated from the adjoining ones; in addition, rapid fire guns of small caliber, intended solely for the purpose of beginning the fight and damaging the non-vital parts of the opposing vessels.

If it is ever accepted as an axiom that the fighting fleet is not intended for cruising, the superstructures of battle ships will be suppressed and the crews quartered on shore; but it is hard work to oppose a practice, adopted by all Navies, which is conducive to perfecting the accommodations of ships at the expense of their fighting powers. All these structures on deck will have primarily the effect of changing a simple shell into shrapnel, and to render the guns powerless by the debris which will cover them. It seems, therefore, that we should begin now to profit by the experiences

acquired, and to reduce as much as possible the volume and the weight of the superstructure.

As the destruction of the lighter armament on the superstructures may be counted on, it is important to provide, behind the armor, several light guns for defence against torpedo boats. Finally, the torpedo being useful at the end of a battle to give the *coup-de-grâce*, there ought to be underwater torpedo tubes, or one shielded by the protective deck.

Under the conditions given above, the role to be played by the torpedo boat becomes of greater importance. Sheltered behind the larger vessels, it may, even in broad daylight, take advantage of the disorder of the battle and the destruction of the secondary battery to dŏ effective work; in any case it will be able, at night, to change, perhaps, an uncertain victory into an irremediable defeat.

The general conclusions to be drawn from the above are as follows:

When a new weapon makes its appearance, it is necessary not only to arm ourselves with it, but also to arm ourselves against it. European powers have been no better advised than were the Chinese when, in adopting rapid fire guns, they continued to build superstructures on their ships as if they had only to send shots and never to receive them.

The true battle ship of to-day can be a sort of monitor only, completely armored, low in the water, invulnerable against light artillery and powerfully armed; speed will be sacrificed to protection and armament. The protected cruiser will be only a despatch boat and the armored cruiser, a privateer with high speed. The figting ship is the monitor.

NOTES.

THE NICLAUSSE BOILERS ON THE *FRIANT*.

The following curves of the power and coal consumption trials of the *Friant* and the explanations are published by the builders of the boilers, Messrs. J. and A. Niclausse, Paris, France. With the exception of the full power trial on March 15, 1895, when all boilers (20) were used, the trials were made with only a part of the boilers.

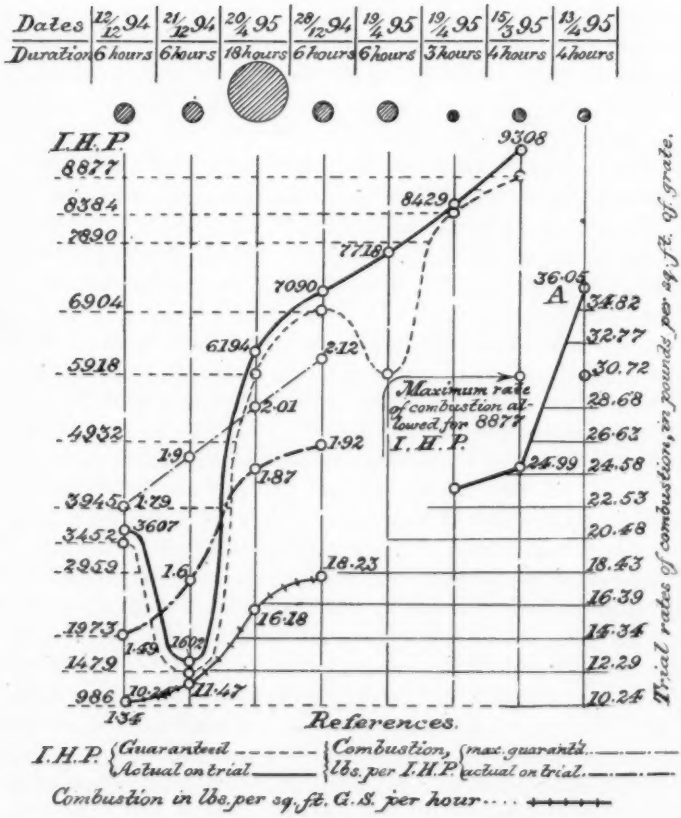
The requirements of the full power trial were that at least 8,877 I.H.P. should be developed with a rate of combustion *not exceeding* 30.72 pounds of coal per square foot of grate surface. As will be seen from the diagram, 9,308 I.H.P. were developed, burning only 24.99 pounds of coal per square foot of grate surface.

The requirements of the forced draft trial of April 13, 1895, were that with 12 out of the 20 boilers under steam the rate of combustion should *not be less* than 30.72 pounds per square foot of grate surface, and that no flame should be produced in the smoke pipes, nor their bases unduly heated. The diagram, point A, shows that 36.05 pounds of coal per square foot of grate surface were consumed in one of the two groups of boilers under steam, the mean I.H.P. for the four hours' trial with both groups of boilers being 6,748. The rates of combustion in the two groups of boilers were different, that of one group being about 16.04 I.H.P. per square foot of grate surface per hour, while the other was about 12.7, the mean for the two groups being 14.37 I.H.P. per square foot of grate surface per hour. These results were obtained without the injection of air *over* the grate bars.

Had all of the boilers during this last trial been under steam, the I.H.P. would have exceeded 10,849.

CURVES OF TRIAL OF "FRIANT."

NICLAUSSE BOILERS.



NAVY ESTIMATES—ENGLAND—1896-1897.

These Estimates were laid before the House of Commons on March 2, and explained by the First Lord of the Admiralty, as follows: The total amount involved is £21,823,000, or £3,122,

000 more than the original Estimates for 1895–1896. Before the close of the present financial year, a Supplementary Estimate of about £1,000,000 will be presented to the House.

The number of officers, seamen, boys, Coastguard and Royal Marines voted for 1895–1896, was 88,850. It is proposed to increase the number by 4,900 for the year 1896–1897, making a total of 93,750. This increase will consist of 61 commissioned officers, 30 subordinate officers, 8 warrant officers, 1,800 men in the seaman class, 342 artisans, 2,028 engine room ratings, 131 miscellaneous and 500 marines. An increase in the authorized numbers in each rank of executive officers below that of flag officer has been sanctioned, and certain changes in the rules of promotion and retirement have been introduced. A new scale of pay has been fixed for engineer officers, with a view to placing the higher ranks more on an equality with the senior officers of the other civil branches of the Navy, and in order to provide adequate remuneration for their increasingly arduous and responsible duties. The list of warrant officers will be further increased, accompanied by a revision of the rules governing their pay, promotion and training.

Of the 100 officers transferred last year from the mercantile marine to a supplementary list of the Royal Navy, to meet the want of executive officers on the active list, 90 were taken from the Naval Reserve, 2 from the Victorian Naval Defense Force and 8 from the Mercantile Marine direct.

The *Britannia* will be replaced by a college on shore for the training of naval cadets.

Increases are proposed in the numbers of officers of various branches of the Naval Reserve.

It is proposed to commence 5 battle ships, 4 first-class cruisers, 3 second-class cruisers, 6 third-class cruisers and 28 torpedo-boat destroyers. Eight of the destroyers have already been ordered, as it was urgently necessary that they should be commenced without delay. Three of the battle ships, one first and one third-class cruiser, will be built in the dockyards, the remaining vessels to be built by contract.

The battle ships will be improved *Renowns* and will have the following principal dimensions: Length, 390 feet; beam, 74 feet; mean load draught, 26 feet; displacement at this draught, 12,900 tons. They will be 2,000 tons smaller than the *Majestic* and draw about 2 feet less water. They will have the same normal coal capacity, 900 tons, and rather greater speed. They will be fitted with water tube boilers, "and will consequently be able to steam further at a high speed than the *Majestic* class." The main armament will be the same as, and the protective arrangement similar to that of the *Majestic* class, but the armor will be lighter. The engines are to develop 15,000 I.H.P., under forced draft, the speed being 18.75 knots.

The first-class cruisers will be of the *Diadem* or *Andromeda* class, (described on page 813, of Vol. VII); the second-class cruisers will be of the *Talbot* type, (described on page 427, of Vol. VII); and the third-class cruisers, of the *Pelorus* type, (described on page 419, of Vol. VII.)

The torpedo boat destroyers are to have a speed of 30 knots.

The following vessels will be under construction in the course of the financial year 1896–'97: 13 first-class battleships, 10 first-class cruisers, 16 second-class cruisers, 7 third-class cruisers, and 48 torpedo-boat destroyers.

For shipbuilding, repairs, maintenance, &c., the estimates are £4,355,000 for the dockyard and £5,386,000 for the contract work.

NOTE.—The number and pay of warrant officers has been increased, and other beneficial changes made, by an order which took effect on April 1. Contracts for the five third-class cruisers have been let, and four of the vessels named. (See under "Ships," England.) The three battleships to be built by the Government will be laid down at the Chatham, Devonport and Portsmouth dockyards.

About the middle of April, arrangements were perfected for the proposed increase of 2,028 engine-room ratings. The engine-room artificers will be increased by 266 and the stokers by 1,762. To fill vacancies and to allow for casualties, the entries for these two grades will be 339 and 2,762, respectively.—EDIT.

TRIAL OF BELLEVILLE BOILERS ON H.M.S. *SHARPSHOOTER*.

The following Parliamentary "Return of Experimental Trials of H.M.S. *Sharpshooter*" has been published.

"I have the honor to report that in compliance with Admiralty letter (S. 14,436) of October 9, 1895, I carried out in Her Majesty's ship under my command the trials mentioned in paragraph 2 of that letter on three occasions, viz.:

"(*a*) At Portland on December 2 whilst at torpedo practice.

"(*b*) Off the Nab on December 10 at target practice.

"(*c*) At Spithead on December 11 at torpedo practice.

"In all cases the ship was manœuvred as she might be in battle, the vessel cleared for action, and the men at their stations for general quarters. Full power for four boilers was used, giving a speed of 13½ knots, 190 revolutions, and 1,450 indicated horse-power.

"The following manœuvres were practised: Stopping frequently from full speed and starting again, without warning, after intervals of five minutes to 1½ hours, getting away at full speed from banked fires.

"All that was found necessary in the stokeholds was to close the draft plates of the furnaces, and open wide the tube box doors, and in the engine rooms to make a moderate use of the blow-off valves to the condensers when suddenly stopping. There was no priming at the engines. Fires were banked on December 9 at 7 P. M., steam maintained all night at 150 to 200 pounds till 8 A. M. on the 10th, when the ship was got under way and started immediately at full speed, and manœuvred, as already mentioned, for six hours. On this trial, as a precautionary measure, a petty officer was stationed at the separator to insure that its blowing-out apparatus did not fail, but the apparatus acted most satisfactorily, and the services of the petty officer were not once required. During the above trials the stokers employed were the men forming the first training class, who had been in the ship about a fortnight.

"I have, &c.,

"(Signed) A. DODGSON,
Lieutenant Commander."

H. M. S. *SHARPSHOOTER*

Number of trial.	Date.	Distance run.	Duration of trial.	Nature of trial.	Indicated horse-power.	Speed by log.	Number of boilers in use (total number, 8).	Grate surface in use.	Total heating surface in use.	Coal. Total during trial.	Coal. Per square foot of grate per hour.	Coal. Per indicated horse-power per hour.	Engines eased From— Date.	Engines eased From— Time.
	1895.	*Miles.*	*Hrs.*					*Sq. ft.*	*Sq. ft.*	*Tons.*	*Lbs.*	*Lbs.*		
1	June 20 to 22	693	48½	Sea..	1553	14.3	6	202	5770	63	14.4	1.87	June 21 June 21 June 22 June 22 June 22	9·20 P. M.... 11·15 P. M... 2·40 A. M.... 3·50 A. M.... 5·45 P. M....
2	June 25 to 28	1000	69	Sea..	1549	14.4	6	202	5770	91.4	14.6	1.91	Engines not eased.....	
3	July 3 to 6	1000	66½	Sea..	1569	15.0	6	202	5770	96.5	16.0	2.07	Engines not eased.....	
4	July 11 to 14	1000	68	Sea..	1554	14.7	6	202	5770	91.8	14.9	1.94	July 11 July 12	11·30 P. M... 11·45 P. M... Banked fires
	July 19 July 23	Trial abandoned on account of bad weather.												
5	July 28 to 31	1000	66¼	Sea..	1804	14.9	6	202	5770	103.4	17.2	1.92	Engines not eased.....	
6	Aug. 7 to 11	1000	69½	Sea..	1820	14.4	6	202	5770	104.2	16.6	1.84	Aug. 9 Aug. 9	8·15 A. M.... 9·30 A. M....
7	Sept. 18 to 21	1000	65	Sea..	2016	15.3	6	202	5770	105.1	17.9	1.8	Engines not eased.....	
8	Sept. 28 to Oct. 1	1000	63½	Sea..	2037	15.7	6	202	5770	103.2	18.0	1.79	Engines not eased.....	
9	Oct. 8 to 13	1000	62	Sea..	2194	16.1	6	202	5770	105.4	18.8	1.73	Oct. 8 11·0 drew banked Continued trial.	8·50 .....

December 2, 1895. Torpedo practice.
December 10, 1895. Target practice....
December 11, 1895. Torpedo practice.
} Indicated horse-power, 1,450; speed by log, about 13.5; number of boilers in use, 4.

SPECIAL SEA TRIALS.

Number of trial.	To— Time.	To— Date.	Cause.	Feeding of boilers; was it regular and constant?	Did boilers prime?	Was there any flaming at the funnels?	Repairs. Main engines.	Repairs. Auxiliary engines.	Repairs. Boilers.
during trials.									
1	10·0 P. M. 1·50 P. M. 3·0 A. M. 8·25 A. M. Discontinued trial at end of 693 miles.	June 21 June 22 June 22 June 22	Thick fog. .....do .....do .....do .....do	Yes	No	No	Nil	Nil	Nil.
2	.....	.....	.....	Yes	No	No	Nil	Nil	Four coned sleeves fitted to feed nipples.
3	.....	.....	.....	Yes	No	No	S.I.P. piston rings broken.	Nil	Two coned sleeves fitted to feed nipples.
4	12 (night) Stopped.	July 11	Heavy squalls.	Yes	No	No	Crack in web of S.H.P. cylinder.	Nil	Nil.
all day, till 1·50 A. M. of the 13th.									
5	.....	.....	.....	Yes	No	No	Crack in brazing of P.I.P. receiver pipe.	Nil	Nil.
6	9·30 A. M. Banked fires and distilling till 2 P. M. of the 10th.	Aug. 9	Squalls and thick fog.	Yes. Crack discovered in plunger of one feed pump; but feed maintained by starting another pump.	No	No	After propeller shaft bearings worn; condenser leaked.	Feed pump plunger cracked.	Nil.
7	.....	.....	.....	Yes. Feeding of one boiler was by hand for part of the time, as a small piece of wire got under the valve of the automatic feed.	No	No	Nil	An obstruction removed from the valve box of one feed pump.	Piece of wire removed from one automatic feed valve. Spindle of one blow-off valve broken.
8	.....	.....	.....	Yes	No	No	Stud of reversing gear broken.	Nil	Nil.
9	.....	.....	Gale of wind, causing engines to race excessively.	Yes	No	No	Bracket of reversing gear broken.	Furnace air engine damaged by a spanner.	One bolt for securing element to feed nipple. Brick work of furnace.
fires in five boilers, fire in one boiler.									
	11'5	Oct. 10							

ABSTRACT OF MANŒUVRING TRIALS (DETAILS ATTACHED).

Ship manœuvred as in action, machinery suddenly stopped (frequently from full speed), starting again without warning after intervals of from five minutes to 1½ hours, getting away at full speed from banked fires. Fires were banked on December 9 at 7 P. M., and steam maintained all night at 150 pounds to 200 pounds, till 8 A. M. on the 10th, when the ship was got under way, and started immediately at full speed and manœuvred for six hours. There was no priming at the engines during these trials.

FRENCH NAVAL REGULATIONS FOR SIZES OF EVAPORATORS.

The regulations published on page 793 of Vol. VII, were modified by a circular dated March 14, 1896, it having been found that there were no evaporators built on the triple system which were light enough or suitable for torpedo boats. Besides, it was noticed that there was little use in making potable water on these boats, which were at sea for a very short time only, and that the weight of evaporator or distiller to be carried for this purpose was out of all proportion to the requirements to be satisfied. It was further found to be illogical to base the size of the evaporators, and the amount of reserve water to be carried, on the power of the engines instead of on the capacity of the boiler and the economy of the apparatus. Besides, "it is a pity to reduce the scantlings of hull and the weights of parts of the machinery to the smallest possible, and then to require a surfeit of means to make and to store fresh water."

The following changes were, therefore, authorized:

1. There is, in general, no objection to using single effect evaporators.

2. The evaporators of torpedo boats are not required to be large enough to supply potable water in addition to fresh water for "make-up" feed. But it is to be required, in future, that the number of days' supply of potable water in the tanks shall always be at least one-half greater than the number of days' steaming endurance at a speed of 10 knots and with the nominal coal supply. To calculate this radius of action, the coal consumption obtained on the trials will be used and increased one-tenth.

3. No modification is necessary in the figures or in the basis of calculation, adopted in the circular of October 8, 1895, for the supply of "make-up" feed water and for the quantity of reserve water.

4. The new requirements are to be applied only to torpedo boats to be built hereafter, and not to those in commission or under construction, except within the limits compatible with their displacement and sea going qualites.

SHIPS.

UNITED STATES.

Iowa.—This sea-going battleship No. 1, was successfully launched on Saturday, March 28, by the Messrs. Wm. Cramp and Sons' Ship and Engine Building Co., Philadelphia, Pa. A description of this vessel was given on page 811, Vol. IV, and the bids on page 202, Vol. V.

Chicago.—This twin-screw, partially-protected cruiser, of 4,500 tons displacement and 5,084 I.H.P., completed by Messrs. John Roach and Sons in 1885, is undergoing repairs at the New York Navy Yard. New machinery and boilers will be put in. The new engines will be of the horizontal, triple-expansion type, similar to those in the *Newark*, and are designed for 9,000 I.H.P. under forced draft. There will be centrifrugal circulating pumps and independent air pumps, made by Mr. M. T. Davidson, Brooklyn, N. Y.

There will be four single-ended cylindrical boilers, one of which will be of nickel steel, and six Babcock & Wilcox water tube boilers. The closed fire room system of forced draft will be used. The cylindrical boilers will be employed for ordinary cruising, and all boilers for full power.

A detailed description of the new machinery will be published when the engines and boilers have been installed.

ARGENTINE REPUBLIC.

Torpedo-boat Destroyers.—The following description of the four destroyers mentioned in the February number, and which are to be built by Messrs. Yarrow & Co., is from the London "Engineer."

The length over all is to be 190 feet; beam, 19.5 feet. The hull will not "tumble home" above the water line, as in the *Sokol*. The bow will be considerably flared out, to throw off the seas, somewhat like the bow of the *Desperate*. The sides and

deck around the machinery spaces will be armored. There will be no water tight doors, although the subdivision by bulkheads will be very complete. The bunker capacity will be about 80 tons. The captain's cabin and officers' mess room are to be next to the engine room bulkhead, instead of the usual arrangement of placing the cabin aft.

The armament will consist of one 14-pounder rapid-firing gun on the conning tower forward; three 6-pounder rapid firing guns on the deck aft; two Maxim automatic machine guns, one on each side above the conning tower; one 18-inch torpedo tube in the bow, and two 18-inch swivel torpedo tubes on deck aft.

There will be two inverted, triple-expansion engines, accurately balanced. They are to develop about 4,000 I.H.P. under forced draft. There will be six Yarrow boilers. There will be two horizontal blowers, with their engines on the fire room floor.

With a load of 35 tons, the speed is to be 26 knots.

AUSTRIA.

Viper.—The official trial of this sea-going torpedo boat, built by Messrs. Yarrow & Co., was made on Friday, January 31, in the presence of representatives of the Austrian Government.

The vessel is 147 feet 6 inches long by 14 feet 9 inches beam, and was guaranteed to attain a speed of 24 knots when fully equipped and loaded with 26 tons to represent armament.

During the middle of the three hours' trial, six runs were made on the measured mile, during which the mean speed attained was 26.633 knots, the mean number of revolutions being 379.89. The mean speed for the three hours' continuous run was 26.638 knots, 2.638 knots in excess of the contract speed, the mean number of revolutions being 379.888 per minute. The average steam pressure was about 174 pounds per square inch; vacuum, 25 inches of mercury; I.H.P., 2,000; air pressure, seven-eighths inch of water. The vibration was practically *nil* at all speeds, the machinery being balanced on the system first introduced by this firm. There is only one triple-expansion engine.

After the run the usual manœuvring trials were carried out, all of which proved satisfactory.

There are two boilers of the Yarrow type, with straight tubes and no outside down pipes. The total grate surface is 70 square feet, and the heating surface, 3,736 square feet. The weight of the two boilers, including water and fittings, is 18 tons. The coal bunkers, on each side of the boiler compartment and one cross bunker forward of the boilers, have a capacity of about 30 tons.

For the trip to Pola, Austria, the *Viper* carried a complement of 23. On her arrival there, the boilers were in excellent condition.

Natter.—A torpedo boat, similar to the *Viper*, is building by Messrs. F. Schichau & Co., Elbing, Germany.

CHILI.

Esmeralda.—This steel, sheathed cruiser, built by Messrs. Armstrong, Mitchell & Co., Newcastle-on-Tyne, was launched on Tuesday, April 14, 1896.

Her length is 436 feet; beam, 53 feet 2 inches; draught, mean, 20.5 feet; displacement, 7,000 tons. There is an armor belt of 6 inches of harveyized steel, 7 feet wide, extending about three-fourths the length of the vessel. At the ends of this belt there are transverse bulkheads 6 inches thick. The protective deck is 1.5 inches thick behind the belt armor, and 2 inches at the ends. The coal bunkers are above the protective deck. The total coal supply will be 1,200 tons at load draught.

The armament will consist of two 8-inch, sixteen 6-inch, eight 12-pounders, ten 6-pounders, four machine guns, and three torpedo tubes, one in the bow above water and one submerged on each broadside.

With natural draft, a speed of from 22.25 to 22.5 knots is expected. It will be remembered that the first *Esmeralda*, built by the same firm for Chili, was sold to Japan.

Ministro Zenteno.—This cruiser was launched by Messrs. Armstrong, Mitchell & Co., at Elswick, on February 1.

She is 330 feet 5 inches long, and has a beam of 43 feet 9 inches, draught, 16 feet 10 inches, and a displacement of 3,450 tons. The expected speed is 20 knots.

The armament consists of eight 6-inch ten 6-pounder Hotch-

kiss, and four 1-pounder Hotchkiss rapid fire guns and 3 torpedo tubes.

The protective deck is 3½ inches thick on the sides and 1¼ inches on the flat top.

Almirante Simpson.—This torpedo gunboat, built by Messrs. Laird Bros., Birkenhead, was launched on April 16, 1896. Her length is 240 feet; beam, 27.5 feet; depth, 16 feet; tonnage, 858 tons, O. M.

The deck and side plating are increased around the machinery compartments.

The armament will consist of two 4.7-inch Armstrong rapid fire guns, four Maxim-Nordenfeldt 3-pounders and three 18-inch torpedo tubes, one in the bow and the others in broadside.

The engines are twin-screw, triple-expansion, and designed for 4,500–5,000 I.H.P. There are four Normand water tube boilers with a working pressure of 200 pounds per square inch. The estimated speed is 21 knots.

Capitan Orella and **Capitan Muniz Gamero.**—These 30-knot torpedo boat destroyers, built by Messrs. Laird Bros., Birkenhead, were launched on February 15 and March 3, respectively. The *Capitan Orella* was ordered in August, 1895.

ENGLAND.

Mars.—This first-class battleship, a sister of the *Magnificent*, fully described on page 161 of Vol. VII, was floated out of the dock of the builders, Messrs. Laird Bros., Birkenhead, on Tuesday, March 31. The principal data are here repeated.

The length on water line is 390 feet; beam, 75 feet; mean draught, 27.5 feet; displacement at this draught, 14,900 tons. I.H.P. and speed, natural draft 10,000 and 16.5 knots; forced draft, 12,000 and 17.5 knots. Coal carried on draught of 27.5 feet, 900 tons; bunker capacity, 1,800–1,900 tons.

The twin-screw, vertical inverted, triple-expansion engines were built by Messrs. Laird Bros. The eight single-ended, return-tube, cylindrical boilers are placed in pairs in four compartments. There are eight blowers, 72 inches in diameter, for forcing the draft. Two additional blowers of the same size are used for

ventilating purposes. The two smoke pipes will be placed in the same athwartship line.

When floated out of dock, the *Mars* carried all her citadel armor, most of the barbette armor, and four casemate fronts; the eight main boilers ready for steam, except the smoke pipes; all of the auxiliary machinery in place, and pipes and connections fitted; and fully two-thirds of the main engines erected on board. The order for the *Mars* was given on March 26, 1894, and the keel laid on June 2, 1894, practically twenty-two months to the date of launching. She will have a complement of 750 men.

Renown.—This first class battleship, described on page 427, Vol. VII, has completed her official trials, with the following results:

	Natural Draft. March 27, 1896.	*Forced Draft. April 6, 1896.*
Duration of trial, hours	8	4
Steam pressure, pounds per square inch, in boilers	146	145
at engines	143.5	.....
Vacuum, inches	26.9	27.25
Revolutions per minute, starboard	97.5	101.6
port	98.2	106.5
I.H.P., starboard	5,233	6,340
port	5,475	6,561
total	10,708.	12,901.
Speed, knots	17.9	18.75
Air pressure, inches of water	.27	.7

The result of the natural draft trial shows that the estimated I.H.P. and speed were both exceeded, the former by 708 and the speed by nine-tenths of a knot, or very nearly that estimated for the forced draft speed. The machinery worked satisfactorily.

On the last hour of the full power trial, one of the cylinder covers of the starboard circulating engine was found to be broken, but this was not allowed to interrupt the trial. After the trial, the other cover of this cylinder was found to be broken.

The propellers are of gun metal, 16.5 feet in diameter, and have a mean pitch of 21 feet.

The boilers are 16.5 feet in diameter and 10.25 feet long, each with four furnaces. The total grate surface of the eight boilers is 793 square feet and the heating surface, 24,840 square feet.

The complement of this vessel will be 674 men.

The I.H.P. on the natural draft trial was distributed as follows: Starboard engine, H.P. cylinder, 1,729; I.P. cylinder, 1,721; L.P. cylinder, 1,783; total, 5,233; port engine, 1,804, 1,731, 1,940; total, 5,475.

On the forced draft trial, the mean pressures were for the starboard engine, H.P. cylinder, 67 pounds per square inch, I.P. cylinder, 27.8 pounds, L.P. cylinder, 13.5 pounds; port engine, 63.6, 28.7, and 13.4 pounds per square inch.

The results of the trials give the most economical speed of this vessel as 15.3 knots, with 6,187 I.H.P., 87 revolutions per minute, and a coal consumption of about 1.88 pounds per I.H.P. per hour. The gun trials were satisfactorily concluded about the middle of April. The two 10-inch guns in each barbette were fired simultaneously at an elevation of 35 degrees directly ahead and astern. The ship has electric motors for the elevating gear of the 10-inch guns and for the ammunition hoists.

The thirty hours' coal consumption trial was finished on April 16. The vessel was loaded to a draught of 26 feet 9 inches, which will be her draught when in commission for sea service. The results are as follows:

Steam pressure, 137 pounds per square inch; vacuum, starboard, 27.8, and port, 26.8 inches of mercury; revolutions per minute, starboard, 85, and port, 88.6; I.H.P., starboard, 3,143, port, 3,044; total I.H.P., 6,187; no air pressure; speed, 15.3 knots; coal per I.H.P. per hour, 1.88 pounds.

The "Naval and Military Record" says: "It is stated that the machinery contractors are so pleased with the performances of the *Renown* on her recent trials, that they have decided to give a bonus to the naval engine room ratings who have worked the vessel through the trials."

Dido.—This protected second-class cruiser of the *Apollo* class was successfully floated on March 20, by the London and Glasgow Engineering and Shipbuilding Co., Govan, Scotland, after having been caught up on the ways since March 17. On this day, the launching ceremony took place, and the vessel moved slowly along until she was about half way in the water, when the

ground near the end of the ways suddenly subsided and the vessel was thrown out of the cradle. She continued to move for some yards before she stopped. An unsuccessful effort was made to pull her off with tugs. On the following two days, the vessel was moved about 60 or 70 feet. A final effort on the third day proved successful. After being floated, examination by a diver showed no damage beyond a slight indentation of the sheathing. This was afterwards proved by examination in dock.

The dimensions of the *Dido* are: Length between perpendiculars, 350 feet; breadth, extreme, 54 feet; mean load draught, 20 feet 6 inches; and load displacement, 5,600 tons. The hull is built of Siemens-Martin steel, and is sheathed with 3½ inches of teak and copper. The sternpost, propeller brackets, rudder frame, and stem are phosphor-bronze castings. The protective deck is from 3 to 1½ inches thick. The cylinders are protected by an armored hatch coaming formed of 5-inch thick harveyized steel plates. The armored conning tower is of the same material, 6 inches thick. The ammunition tubes are of fluid-pressed steel. Bilge keels of teak, covered by naval brass plates, are fitted for about 156 feet amidships. The armament of the vessel will consist of five 6-inch, six 4.7-inch, nine 12-pounder, and seven 3-pounder quick firing guns, and a number of smaller machine guns; one torpedo tube with 3-inch steel mantlet, discharging above water aft, and two submerged tubes on broadside forward, all fitted for 18-inch torpedoes. The steam steering gear is by Napier Brothers; the auxiliary hand steering gear is a new compensating gear specially designed at the Admiralty for the *Dido* and *Isis*. The two sets of triple-expansion engines, which are supplied by the builders, have cylinders 33, 49 and 74 inches in diameter, with a stroke of 39 inches. Each cylinder is fitted with a liner, and is steam jacketed. The high pressure cylinder is fitted with a piston valve; the intermediate and low pressure cylinders have double-ported slide valves, with relieving rings and balance cylinders. The main condensers are of brass. There are in each engine room two duplex fire and bilge pumps, one main feed pump, an auxiliary condenser with its pumps, and a dynamo driven by a compound engine. There are two auxiliary

feed pumps in each fire room. There are two boiler rooms, each containing four single-ended boilers, each boiler having three corrugated furnaces. The working pressure will be 155 pounds. There are four blowers in each fire room.

Doris.—This sheathed second-class cruiser was launched at Barrow on March 3. She is a sister ship to the *Juno*, launched on November 16, 1895, by the Naval Construction and Armaments Company, and described on page 169, of Vol. VIII. The protective deck extends the whole length of the vessel, the engines, boilers and magazines being further protected by an inclined breastwork of harveyized armor. Bunker accommodation is provided for 1,000 tons of coal, reserve coal being stowed in water tight bunkers above the protective deck and extending over the engine and boiler space. There is an armored conning tower forward and a director tower aft. There are two military masts. The complement will be 450 officers and men.

Pelorus.—This third-class, twin-screw, protected cruiser, a brief description of which was given on pages 419 and 601, Vol. VII, was launched from the Sheerness dockyard on February 15. She is the first one of this type, the keel having been laid May 21, 1895. The length is 300 feet; beam, 36.5 feet; load displacement, 2,135 tons, on a draught of 12 feet forward and 15 feet aft.

The hull of the vessel is constructed of steel, and her vital parts are protected by a turtle-back deck, throughout her length, of steel plating, 2 inches thick, the stern and rudder posts, shaft brackets, &c., being of cast steel. The rudder is of the balanced type, and is worked by steam steering gear. The vessel has a poop and forecastle, and between them the waist extends to about half her length, the officers' quarters being aft under the poop and the crew being berthed forward.

The armament will consist entirely of quick firing guns, of which there will be eight 4-inch, eight 3-pounder, and two .45-inch Maxim guns, two of the 4-inch guns being mounted on either side of the conning tower on the forecastle and two on the poop, the remaining guns being distributed on the upper deck and at the bow and stern. There will be two 14-inch torpedo tubes.

The propelling machinery, which is to be supplied and fitted by Messrs. J. and G. Thompson of Clydebank, will consist of two independent sets of inverted triple-expansion engines, with cylinders 20½, 33 and 54 inches in diameter, which are expected to develop 7,000 I.H.P. under forced draft with about 200 revolutions per minute, and give the vessel a speed of 20 knots.

There will be eight Normand water tube boilers.

The bunkers, consisting of 28 separate compartments, part above and part below the protective deck, will have a capacity of 550 tons. The steaming radius at 10 knots will be about 7,000 nautical miles. There are two wooden masts, each in two lengths. There are two dynamos. The complement of officers and men will be 225.

Perseus, Prometheus, Pegasus, Pyramus and ——.—These third-class cruisers of the *Pelorus* type, recently authorized, have been ordered. The first two are to be built by the Earle Shipbuilding Company, Hull, and the next two by the Palmer Shipbuilding Company, Jarrow-on-Tyne. The length will be 300 feet; beam, 36.5 feet; mean load draught, 13.5 feet; displacement at this draught, 2,135 tons. The I.H.P. is expected to be 5,000 with natural draft and 7,000 with forced draft, and the corresponding mean speeds, 18.5 and 20 knots for eight and four hours' steaming, respectively. Water tube boilers will be installed.

The armament will include eight 4-inch and eight 3-pounder rapid firing guns and two torpedo tubes.

The estimated cost of each vessel is $710,000 and the time of completion, fifteen months.

Another cruiser of this class is to be built by Messrs. Armstrong, Mitchell & Co., Newcastle, but no name has yet been made public.

Barham and **Bellona.**—These cruisers are to be thoroughly overhauled, and their locomotive boilers replaced by Thornycroft water-tube boilers. The amount allowed for the refit of each vessel is $141,090, of which $52,500 is for the installation of the new boilers, and $75,000 for alterations and repairs to hull, fittings, and equipment.

The *Barham* was built at the Portsmouth dock yard in 1890, and cost $507,765. Since that time she has only been commissioned for one cruise, and $41,700 have been spent on repairs and alterations.

The *Bellona* was built by Messrs. Hawthorne, Leslie & Co., Newcastle, in 1891, and cost $455,740. Since that time she has been in commission for three years and nine months, and $45,000 have been spent on repairs and alterations.

Phaeton.—This cruiser, built in 1886, and recently overhauled, completed satisfactory steam trials off Plymouth in the latter end of March. The mean results for the four hours were: Steam pressure, 83 pounds per square inch; vacuum, starboard, 26.3, and port, 27.6 inches; revolutions per minute, starboard, 93.1, and port, 93.4; I.H.P., starboard, 2,318, and port, 2,437; speed, 17 knots. The trial was made under natural draft. This result, 4,755 I.H.P. and 17 knots, compared favorably with that obtained in 1886, when the I.H.P. was 5,000 and the speed 16.6 knots.

The vessel was overhauled, after seven years in foreign service, at a cost of $164,160, of which about $136,590 was expended on hull, fittings, and armament, and about $27,570 on the machinery.

Spanker.—This torpedo gunboat, recently fitted with Du Temple water-tube boilers, at Devonport, had an eight hours' trial under natural draft on February 13, and a four hours' trial under forced draft on the following day, with the following results:

	Natural.	*Forced.*
Duration of trial, hours	8	4
Steam pressure, pounds per square inch	149	149
Vacuum, inches of mercury, starboard	27.7	27
port	28.3	27
Air pressure, inches of water	1.48	3.59
Revolutions per minute, starboard	252.1	277.7
port	245.3	275.7
I.H.P., starboard	1,356	1,991
port	1,403	1,929
total	2,759	3,920
Speed, in knots, by log	18.3	20

After examination of the machinery, further trials, similar to those made with the *Sharpshooter*, will be made.

Algerine.—This sloop completed her forced and natural draft trials on February 17, with the following results:

	Natural.	*Forced.*
Duration of trial, hours	8	4
Steam pressure, pounds per square inch	150	150
Vacuum, inches of mercury, starboard	27.6	27.1
port	27.5	27.4
Air pressure, inch of water	0.38	0.8
Revolutions per minute, starboard	186.7	209.2
port	197.7	197
I.H.P., starboard	618	731
port	588	759
total	1,206	1.490
Speed, in knots, by log	12.7	13.1

Handy, Hart and **Hunter.**—The following description of the machinery of these destroyers is taken from "Engineering," London:

These 27-knot torpedo boat destroyers, *Handy*, *Hart* and *Hunter*, all three of which have successfully passed through their speed trials, were built by the Fairfield Shipbuilding and Engineering Company, Glasgow, and are 194 feet long by 19 feet 4½ inches beam, and 12 feet 7½ inches deep, their displacement in service trim being 245 tons. They are, like the other vessels of the class, armed with one 12-pounder and five 6-pounder guns.

The machinery, which was designed by Mr. Andrew Laing, consists of two three-cylinder triple-expansion engines, with cylinders 18¼, 27½ and 42 inches in diameter, the stroke being 18 inches. All have piston valves. The cylinders are of cast iron, and with each was cast also the valve casing. The cylinder and casing bottoms, which are separate from the cylinders, are also of cast iron. The cylinder covers, however, are of cast steel and of light design, while the casing tops are of rolled steel plate and dished to give the necessary stiffness.

The pistons are of the conical or dished pattern, made of high tension forged steel by Sir Joseph Whitworth & Co., of Manchester. The connecting and piston rods are made of forged mild steel and bored. The guide shoes, which are separate from the piston rods, are of gun metal lined with white metal, and

they can be readily adjusted. The guides, which are of cast iron, are attached, one at the top end to the cylinder bottom, the other to a crossbar midway down the columns, and it in turn is held in place by the cross stays. The valve gear is of the usual bar link and double eccentric type, the eccentric rods being made of mild steel with adjustable gun metal bushes at the top end. The straps are also of gun metal and lined with white metal. There is steam and hand reversing gear of the all-round description, the reversing engine having one cylinder, $3\frac{1}{4}$ inches in diameter and $2\frac{1}{2}$ inches stroke, and the reversing and drain gear being arranged at the forward end of each set of engines.

The three-throw crankshaft is made of mild steel and in one piece; the body of the shaft and crank pins are 6 inches in diameter with a 3-inch hole. The crank, crank pin, cheeks and moving gear have been carefully balanced by means of weights suitably placed. The line shaft is 6 inches in diameter with a $3\frac{1}{4}$-inch hole; the propeller shaft is $6\frac{1}{4}$ inches in diameter, with a $3\frac{1}{4}$-inch hole bored throughout. The thrust blocks are of the ring description, of cast iron, and lined with white metal at the bearings; the block is also water jacketed.

The cylinders are each supported on four wrought-steel columns, their bottom ends passing through the cast-steel bearers, being fastened thereto by nuts on the underside. The bearers are of H-section. The main bearing brasses are of gun metal, lined with white metal, and are held in position by wrought-steel caps, each having two steel studs. The cross bearers are bolted at each end to the fore-and-aft portions of the bed plates, which are made from rolled steel angle bars, these bars being planed on the face and bottom. The fore-and-aft portions of the bed plate or angle bars are continued forward to receive the air pump, and aft to carry the thrust blocks. By this means the engines are complete and self-contained, so that all strains are well distributed over the shipwork.

Diagonal bracing of the cylinders is dispensed with, the cylinders for each set of engines being bolted together in a fore-and-aft direction, but diagonal stays are carried from the cylinders

to the fore-and-aft bulkheads. The cylinders of the two sets of engines are tied together athwartships and also to a fore-and-aft stiffener at the ship's sides.

The engines are so placed in the engine room that there is a passage between, and also between the engine and its corresponding condenser, which is in the wings and on a low level. The condensers, with their tubes and ends, are of brass, the steam being led in on the top and diagonally to give free distribution. Circulating water to the condensers is supplied by the two centrifugal pumps, having 8-inch discharges, and sufficient for moderate powers. The centrifugal engines and pump were supplied by Thwaites Brothers, Bradford. The air pump is single-acting, 18½ inches in diameter, and has a stroke of 4 inches. The head and foot valve and the bucket are fitted with metal annular group valves. The pump is driven by a separate crankshaft from the end of the main crank.

The boilers, three in number, are arranged two in the after boiler compartment and one in the forward. They are of the Thornycroft Daring type modified. The generating tubes are arranged in nearly equal groups, instead of two large and two small groups. Each boiler has 63 square feet of grate surface, and 3,168 square feet of heating surface. The boilers are constructed for a working pressure of 210 pounds, and were tested to 300 pounds per square inch. The steam drums are fitted with the usual Thornycroft steam drying arrangement and automatic feed control gear. During the trials, the boilers gave abundance of dry steam, with much less trouble than the ordinary drum boiler. The main feed donkey pumps, two in number, were supplied by Messrs. G. and J. Weir, of Glasgow, and are placed, along with the evaporating and distilling plant, air compressing engine, and bilge engine, at the forward end of the engine room, convenient to the starting gear.

In the after boiler compartment, there are two 5.5-foot single inlet fans, for supplying air to the furnaces, and one auxiliary duplex feed donkey capable of feeding the two boilers; and in the forward stokehold, one 5.5-foot single inlet fan, and one auxiliary duplex feed donkey. The fans were supplied by Messrs.

W. H. Allen & Co., of Bedford, and the duplex pumps by Messrs. Scott & Mountain, of Newcastle-on-Tyne.

The steering engine, supplied by Messrs. Caldwell & Co., Glasgow, is placed with its cylinders vertical, fixed to the after engine room bulkhead.

There are two funnels; that forward is for the boiler in the forward compartment, as well as for one of the boilers in the after boiler space, and the after funnel is used for the remaining boiler, and also in connection with the ventilation of the engine room.

	Hart.	*Handy.*	*Hunter.*
Date of trial, 3 hours full power	Dec. 31, 1895.	....	Apr. 17, 1896.
Draught, mean, feet and inches	6–3⅜	....	6–3
Steam in boiler, pounds per sq. inch	196.1	189.8	195.
Vacuum, inches of mercury	....	24 5	....
Air pressure, inches of water	2¾	3.19	....
Revolutions per minute	196.1	*S.*, 384.01 *P.*, 392.35	....
I.H.P	4,143	4,451	4,245
Speed, knots	27.075	27.006	27.245
Coal per I.H.P. per hour	3.2	....	....

On March 21, the *Handy* left Portsmouth to rejoin the Channel Squadron. Some time later the tubes of one of the after boilers began to leak badly, owing to shortness of water caused by a wrong showing of the water gauge. The vessel was steaming at about 16 knots. She returned to Portsmouth, where an examination showed that the boiler was not seriously damaged. The leaky tubes have been replaced.

Opossum.—This torpedo boat destroyer, built and engined by Messrs. Hawthorn, Leslie & Co., Newcastle-on-Tyne, completed her official full-speed trials on February 3, with very satisfactory results. This vessel is a sister ship to the *Sunfish*, the trial of which was referred to on page 181 of the February number. She is 200 feet long, and has a beam of 19 feet. The dimensions of the triple-expansion engines, and of the eight Yarrow water tube boilers, and the trial data are given under *Ranger*. The propellers are three-bladed, 7 feet in diameter, and have a pitch of 9 feet, the area of each being 13 square feet.

Ranger.—This destroyer, built by Messrs. Hawthorn, Leslie & Co., Newcastle, completed her official trials at Sheerness on April 1. She is a sister vessel of the *Opossum* and *Sunfish*.

The mean results of the three hours' run were as follows: Steam pressure, 194 pounds per square inch; vacuum, 24.5 inches of mercury; revolutions per minute, 348.25; I.H.P., 4,055; speed, 27.172 knots; air pressure, 3.07 inches of water. The displacement at beginning of the trial was 278 tons, the draught being 5 feet forward and 8 feet 1½ inches aft.

The armament will consist of one 12-pounder and five 6-pounder rapid-firing guns.

The engines are triple-expansion, with cylinders 18½, 28, and 42 inches in diameter, and a stroke of 18 inches.

The condensers have a total cooling surface of 3,000 square feet.

The eight boilers are of the Yarrow type, each with a grate surface of 21 square feet and a heating suface of 1,063 square feet.

The mean speed for the six runs on the measured mile was 27.093, or less than the average for the three hours.

For purposes of comparison, the trial results of the *Sunfish* and *Opossum* are added.

	Sunfish.		*Opossum.*		*Ranger.*
Draught of water on trial, forward, feet and inches	5–1		5–0		5–0
aft, feet and inches	8–1		8–1¼		8–1½
Displacement, tons, about	282		279.		278.
Speed, mean of six runs, knots	28.08		28.242		27.093
three hours, knots	27.581		27.131		27.172
Steam pressure, pounds per square inch	188.		192.		194.
	St'b'd.	*Port.*	*St'b'd.*	*Port.*	
Mean pressure in H.P. cylinders	81.4	82.8	81.9	80.3	
I.P. cylinders	35.4	35.9	33.9	34.1	
L.P. cylinders	15.1	15.4	13.6	14.9	
Vacuum, inches	25.3	24.1	26.6	26.5	24.5
Revolutions, per minute	353.8	349.8	341.6	344.3	348.25
I.H.P., H.P. cylinder	702	707	683	674	
I.P. cylinder	702	704	650	657	
L.P. cylinder	676	683	585	646	
I.H.P., total	2080	2094	1918	1977	
both engines	4174		3895		4055
Air pressure, in inches of water	2.95		3.1		3.07

Haughty.—Since the trial in December, and recorded on page 180 of the February number, this torpedo destroyer has made

several trials. One trial was interrupted by fire breaking out in one of the bunkers, and another one by the breakdown of the blower engines. The blower, 4 feet 6 inches in diameter, collapsed suddenly, while making between 600 and 700 revolutions per minute. The broken pieces bent the adjoining steam pipes, but did not break them. The steam pressure was 200 pounds per square inch.

On April 2, a satisfactory three hours' trial under full power was made. The mean speed for the six runs on the measured mile was 27,949 knots. For the three hours the steam pressure was 188 pounds per square inch; I.H.P., 4,224; number of revolutions per minute, 363.4, and speed, 27.525 knots.

Porcupine.—This destroyer, launched on September 19, 1895, by the Palmer Company, at Jarrow, had an unsuccessful trial on February 4. The trial was stopped on account of excessive priming, supposed to be due to a leaky condenser. For two hours the I.H.P. was 3,129, and the speed 25 knots. On February 19, the official trials were successfully made off the mouth of the Thames, with the following results:

The mean speed on the three hours' run was 27.915 knots, the revolutions being 361.4 per minute, the boiler pressure 197 pounds per square inch, and the air pressure, 2.2 inches. The mean I.H.P. was 3,859. The speed on the six runs on the mile was 27.989 knots.

The automatic feed regulating device, designed by Mr. J. W. Reed, the managing engineer to the contractors, who is also the designer of the boilers, is reported to have worked in a satisfactory manner during the trial, hand regulation being unnecessary. There was an absence of flame from the funnel, the average smoke being "light brown." A complete method of automatic lubrication has been fitted to the engines, no syringing or other hand oiling being used during the trial. After the speed trials, the usual starting, stopping and steering trials were gone through satisfactorily.

This vessel is a sister to the *Janus* and *Lightning*, built by the same company, and is 200 feet long, the beam being 19 feet 9 inches, and the load displacement, 280 tons.

The armament consists of one 12-pounder gun mounted on top of the conning tower, and five 6-pounders, one of these being mounted on an elevated platform aft. There are also two revolving torpedo tubes.

The officers' quarters are abaft the engine room, and the crew's quarters forward, where there is room for fifty men.

The two triple-expansion engines are in one, and the four Reed water-tube boilers in two compartments.

Desperate.—The first of the six 30-knot destroyers to be built by Messrs. J. I. Thornycroft & Co., Chiswick, was launched on February 15. A complete description of this class was given on page 182 of the February number of the JOURNAL. The conditions of the trial laid down by the Admiralty for this class of vessels are novel and somewhat exacting, says "Engineering," London, from which the following information is taken.

The weight of coal, gear, &c., to be carried on trial, is 35 tons, 5 tons more than the 27-knot destroyers. If the coal consumption at *full speed* exceeds 2.5 pounds per I.H.P. per hour, an additional weight of 2 tons for every one-tenth of a pound of coal that the consumption exceeds 2.5 pounds will have to be carried.

The contract also provides that, if a given power is exceeded in obtaining the speed, additional weight shall be carried. This is accounted for by the necessity for carrying bigger crews with bigger powers, and this means additional accommodation, which in turn represents more weight. It is strange "that the coal economy should be taken at the full speed. It is not possible to construct machinery that shall be at its maximum economy over wide ranges of speed. If the engines are big enough for high power, they will be extravagant at lower powers; if they are small for the power, expansion must be curtailed. For the purposes of warfare it would seem desirable to design the engines of these craft so that when making long trips they should be economical, but when full power is required, fuel economy might be neglected."

Preliminary trials were made by the contractors, the fifth and sixth trials resulting as follows:

Fifth trial, Friday, March 20. Vessel light, only 15 tons carried. Weather very rough. Mean speed of four runs over the

Maplin mile, 31.035 knots. Steam pressure, 205 pounds per square inch; vacuum, 25 inches; revolutions per minute, 396; I.H.P., 5,700. Coal consumption, above the standard of 2.5 pounds per I.H.P.

Sixth trial, Tuesday, March 24. Vessel carried standard load of 35 tons. Weather quite favorable. Mean speed of one hour's steaming, including six runs over the mile, 30.46 knots. Steam pressure, 210 pounds per square inch; vacuum, 24 inches; revolutions per minute, 406; I.H.P., estimated from curve of previous trials, 5,600. Engines and boilers worked satisfactorily. Coal consumption, above the standard.

On Thursday, April 16, the official speed trial was made, the vessel carrying the required 35 tons. There was a rough sea and strong wind. Coal, for use on the runs to and from the trial grounds only, was weighed and put in bags. A sufficient quantity of coal was put in the bunkers for use during the three hours' trial only. At the end of the trial, the bunkers were sealed and later the weight of coal remaining in them was ascertained. The mean results of the trial were as follows: Steam pressure, 209 pounds per square inch; vacuum, 24 inches; revolutions per minute, 398; I.H.P., 5,620; coal consumption, 2.491 pounds per I.H.P. per hour; speed for the three hours, 30.112 knots; air pressure, 3.5 inches of water. The coal was burned at the rate of about 80 pounds per square foot of grate surface per hour. Before this trial, Messrs. Thornycroft had fitted an arrangement by means of which air at 10 pounds to the square inch pressure is introduced at the front about 2 feet above the fire, there being 9 or 10 jets to each furnace. This was found on the official trial to give very good results, the quantity of smoke being much reduced, and the flame, which so often results from the escape of unburnt gases, being entirely absent from the chimney tops.

Fame.—A sister destroyer of the *Desperate* was successfully launched by Messrs. Thornycroft & Co., on Wednesday, April 15, 1896. The boilers and engines were on board, and the vessel was practically complete.

Thirty-Knot Torpedo Boat Destoyers.—In addition to the

twelve destroyers, described on page 820, of Vol. VII, Messrs. Laird Bros. are to build the *Earnest*, *Griffon*, *Locust*, *Panther Seal* and *Wolf;* Messrs. Thornycroft & Co., the *Angler* and *Ariel;* The Naval Construction and Armaments Company, the *Avon* and *Bittern*, and Palmer's Shipbuilding Company, the *Bat*, *Chamois*, *Crane*, *Flying Fish*, *Star* and *Whiting*.

Several others have been ordered by the Admiralty, but not yet named.

Thirty-two-Knot Torpedo Boat Destroyers.—The Admiralty have contracted for two of these vessels, one to be built by Messrs. J. I. Thornycroft & Co., Chiswick, and the other by Messrs. J. and G. Thompson. They will be larger than the *Desperate* class, and have more power. There will be four boilers instead of three.

FRANCE.

Carnot.—The following description of this battleship, some particulars of which were given on page 618, Vol. VI, of the JOURNAL, is compiled from "Le Yacht," Paris:

In this vessel the "splinter-deck" system, which in other battleships is applied only over the machinery spaces, has been extended throughout the whole length of the vessel. The space between the protective and the splinter deck below it averages, in the *Carnot*, about 2.3 feet. Two longitudinal wing bulkheads are fitted below the protective deck and give protection against the explosion of torpedoes. A central bulkhead runs through the machinery and central turret spaces. There is the usual subdivision of the main compartments. Beginning forward, the space below the protective deck is taken up by various compartments for store rooms, then a group of compartments for the magazines and turret turning gear for the three forward guns; then four boiler compartments, two abreast; then two groups of compartments, one on each side, for magazines and turret turning gear of the six central guns; then two boiler compartments; then the two engine compartments; then a group of compartments for the magazines and turret turning machinery of the three after guns, and abaft these, the steering engine compartment.

The protective deck, 2.76 inches thick, has a considerable fore-and-aft curvature, being 3.94 feet above the water line in the middle of the vessel and running down to the water line at the ends.

The lower or main armor belt extends 5.58 feet below the water line and 1.8 feet above it in the middle of the vessel. Its thickness at the top tapers from 17.72 inches in the middle of the vessel to 11.81 at the ends; at the bottom, it averages 6.35 inches. This armor belt projects beyond the hull. The protective deck rises from the top edge of this belt. On top of this belt is another one, 3.94 inches thick, the top edge of which is 5.58 feet above the water line. Above this upper belt, the vessel "tumbles in" very appreciably for the purpose of permitting the guns in the six central turrets to fire ahead and astern. The beam of the vessel at the lower level of the superstructure is only about half that at the armor belt. The superstructure is enormous, and consists of three decks, giving the vessel the appearance of an old line-of-battle ship. The superstructure is said to be necessary for living quarters and storerooms, on account of the space occupied by the turrets and their armored trunks or supports, and the absence, practically, of storeroom space below the protective deck. There are, altogether, twelve turrets—three forward, three on each side in the middle of the length, and three aft. The lower deck of the superstructure extends the whole length of the vessel; the next one above, only as far aft as the after military mast; and the next above this extends the same distance aft, but stops some distance from the bow.

The ram is very short and its point well below the water line. There are two heavy military masts, each with three tops. There are two rectangular smoke pipes.

The conning tower for the captain—5.91 inches thick—surrounds the forward mast; above it is a station for the admiral. A similar station is provided on the after mast.

The twelve heaviest guns are in separate, closed turrets. Besides these, there are four 2.56-inch, sixteen 1.85-inch, six 1.46-inch rapid fire guns and four torpedo tubes, two of these being

forward on the protective deck, and one on each broadside, under water.

The two 11.81-inch guns have an angle of fire of 135 degrees on each side of the center line, the forward gun being 27.88 feet, and the after one, 21.32 feet above the water line. The two 10.63-inch guns in the central turrets have an angle of fire of 180 degrees, and are about twenty-one feet above the water line. Four of the 5.51-inch rapid fire guns, in the turrets forward and aft, have an angle of fire of about 150 degrees, and the remaining four, in the broadside turrets, 180 degrees. These last four and the two after ones are 14.76 feet above the water line.

The turret armor of the 11.81-inch and 10.63-inch guns is 14.6 inches, and of the 5.51-inch guns, 3.94 inches thick.

There are six search lights, one in the upper top of each mast, two on the upper deck abaft the turret for the 11.81-inch gun and two on the middle deck forward of the central turrets.

The d'Allest boilers of this vessel were described in detail on page 385, Vol. VII.

Amiral Trehouart.—This battleship was described on page 750 of Vol. V, under the name of *Trêhouart*. Last year this name was changed to its present form. In the latter part of February, she had her preliminary trials, making 15.8 knots over the measured mile, with an average of 110 revolutions per minute.

Bouvines.—This battleship completed a four hours' natural draft trial in the early part of March, the mean speed over the measured mile being 15.3 knots. All boilers were used. The results of the official trials were given on page 604 of Vol. VII.

Jauréguiberry.—This battleship, described on page 616 of Vol. VI., had preliminary trials on April 2. The mean of four runs over the measured mile off the Hyères islands gave a speed of 17.65 knots, the revolutions being 85 per minute, and the coal consumption satisfactory. In the latter part of April, another preliminary trial was made, the speed over the measured mile being 18.07 knots, the I.H.P., 15,583.5 and the revolutions, 100 per minute.

Foudre.—This vessel, built as a torpedo transport or depot ship, and launched on October 20, 1895, was described on page

824 of Vol. VII. The Superior Council of the Navy Department has reported unfavorably against the use of this vessel as a torpedo boat transport, as there are certain difficulties in launching these boats during an action. Plans are under discussion for transforming this vessel into a cruiser, with an armament of 5.51-inch rapid fire guns.

Bugeaud.—This second-class cruiser, particulars of which were given on page 408 of Vol. VII, had a trial in free route on February 20, after changes in the ventilating system had been made. A speed of 18.9 knots was attained. Further slight changes in the ventilating system were found to be necessary. On February 28, another trial was attempted, but was interrupted by the heating of one of the eccentric straps.

Two of the required coal consumption trials (see page 409, Vol. VII) were next made, the first one, on March 11, being an eight hours' trial with only the eight after boilers. The I.H.P. developed was 1,479, with a coal consumption of 1.54 pounds per I.H.P. per hour. This was well within the penalty rate of combustion.

On April 4, the second trial at 3,452 I.H.P. was made. Only two groups of boilers were used. The revolutions were 102 per minute and the speed on the measured mile 15.2 knots. The coal consumption was 1.57 pounds per I.H.P. per hour, or 0.19 pounds less than the maximum allowed.

The above results of the Belleville boilers of this vessel may be compared with those of the Niclausse boilers of the sister ship *Friant*, published under "Notes" in this number of the JOURNAL.

About the middle of April, another full power trial was made, the I.H P. being about 8,900 and the speed, 19 knots.

D'Assas.—This second-class cruiser, a sister ship of the *Cassard* and *Du Chayla* (the principal data of the latter were given on page 188 of the February number), was launched on March 28, by the Societé de la Loire, at St. Nazaire.

The contract for this cruiser was signed in November, 1893, and she is to be finished in February, 1897.

The coal capacity is 604 tons.

The complement will be 22 officers and 371 men.

Galilée.—This third-class cruiser, of an enlarged *Forbin* type, was launched on April 28 at the Rochefort dock-yard.

The principal dimensions are: Length, 328.1 feet; beam, 35.11 feet; displacement, 2,244 tons.

The armament will consist of rapid firing guns only, four 5.45-inch guns being placed in broadsides and having 2.13-inch shields; two 3.94-inch guns, one on the forecastle and one on the poop; eight 1.85-inch and eight 1.46-inch guns distributed over the vessel.

The twin-screw engines are of the vertical triple-expansion type. The I.H.P. and speed expected with natural draft are 3,945 and 18 knots, and with forced draft, 6,510 and 20 knots.

Cassini.—This torpedo cruiser, after several attempts at her full power trials (noted on page 191 of the February number), has completed her natural and forced draft trials. The former was made on February 25, the speed being over 19 knots. On the 29th, the full power trial took place, the speed being 21.174 knots and the I.H.P., 5,517. Although the speed did not quite come up to the 21.5 knots expected, the vessel has been accepted.

Surprise.—This steel, sheathed gunboat, built by Mr. Normand, Havre, and described on page 205 of Vol. VI, has completed her trials.

On her preliminary trials in February, a speed of 13.6 knots was obtained with 984.2 I.H.P. After some changes made in the tubes of her boilers, the official trials were made, the full power trial on March 19 resulting as follows: Revolutions per minute, 148; I.H.P., 841; speed, 13 4 knots. On the natural draft trial, March 24, the I.H.P. was 690, and the speed over 12 knots. The contract requirements were slightly exceeded.

The bunker capacity of this vessel is about 72 tons. She will carry a complement of 6 officers and 93 men.

Casabianca.—This torpedo boat destroyer had her preliminary trials off Rochefort about the middle of February, attaining 19.45 knots without forcing.

Aquilon.—This sea going torpedo boat, described on page 191 of the February number of the JOURNAL, had progressive trials on January 27, during which the machinery was run up to 360

revolutions per minute, the corresponding speed being 25.8 knots. The official trials, held on January 30, resulted in a mean speed of 26.17 knots, or 1.17 knots over the required speed. The contractor, Mr. Normand, will, therefore, receive a premium of $4,680.

GERMANY.

Ersatz Leipzig.—The following particulars of this first-class triple-screw cruiser are in addition to those given on page 827, Vol. VII.

The side armor, extending completely around the vessel, will be of Krupp steel, 7.55 feet wide, varying in thickness from 7.87 to 3.94 inches. The protective deck will be of nickel steel, and join the belt armor at its upper edge. Forward and aft there will be an additional nickel steel, curved protective deck. There will be a splinter deck over the engine and boiler compartments.

The two 9.45-inch guns will be in turrets; the twelve 5.9-inch rapid fire guns will be in armored casemates; the ten 3.46-inch rapid fire guns will be protected by shields.

There will be three separate engines, which, with full power, are expected to give the vessel a speed of 19 knots.

The coal supply at normal draught will be about 985 tons.

HOLLAND.

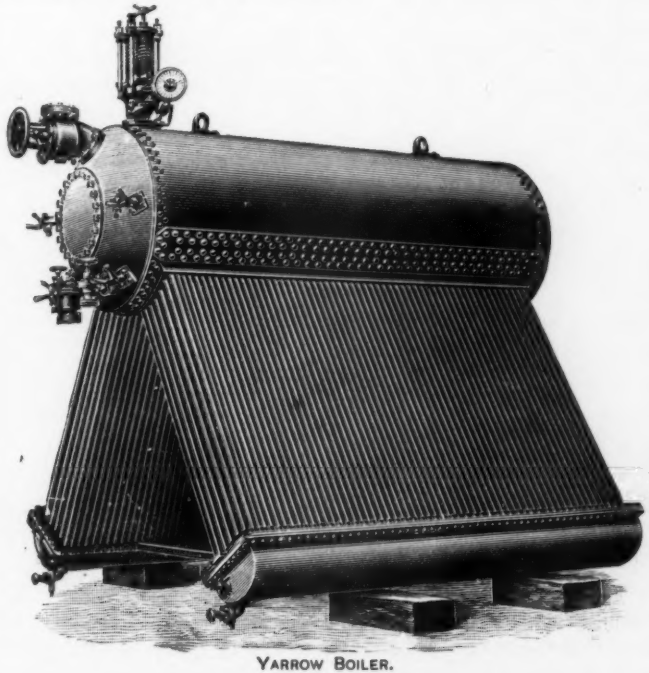
Friesland, Holland and Zeeland.—These cruisers, building in Holland, were described on page 829, Vol. VII. The following additional information, from Messrs. Yarrow & Co. and from "Engineering," London, is available.

The I.H.P. is to be 9,250, an increase over the first design. The two cylindrical boilers in each vessel are to supply steam for 2,250 I.H.P., the eight Yarrow boilers supplying steam for the remaining 7,000 I.H.P. The cylindrical boilers are to be used for ordinary cruising, and the water tube boilers for emergency cases or higher speed, but chiefly for the purpose of instructing the firemen of the Navy in their working.

Of the twenty-four water tube boilers required for the three vessels, Messrs. Yarrow & Co. have built only three, the others

to be built in Holland from them as patterns, and according to designs furnished by Messrs. Yarrow & Co. The JOURNAL is indebted to Messrs. Yarrow & Co. for the cuts of these boilers.

The tubes are straight, of steel, about $5\frac{1}{2}$ feet long between drums and $1\frac{1}{8}$ inches in diameter. There are five rows on each side of the furnace, each row containing about sixty-four tubes. The grate surface of each boiler is 40.25 square feet and the heating surface, 2,017 square feet.



YARROW BOILER.

The two cylindrical boilers will weigh, with water, 120 tons, and the eight Yarrow boilers, with water, 88 tons. These weights include the grate bars and fittings, but not smoke pipes. These figures give 119.47 pounds of cylindrical and 28.16 pounds of water tube boiler per I.H.P. to be developed.

The cylindrical, three-furnace boilers are 13 feet in diameter by 10 feet 6 inches long, exclusive of uptake, which adds another 2 feet. The Yarrow boilers are 9 feet 3 inches high to top of the casing, which includes the steam drum, 9 feet 3 inches wide and 9 feet long over casings. The top cylinder, or steam drum, extends 1 foot further at each end, the total length of the drum being 11 feet. As the steam drum is overhead, it does not encroach upon the stoking space, but the extra foot at the back must be added to get the total length of the water tube boiler, or 10 feet.

The arrangement of the boilers is as follows: In the after boiler compartment, which is just forward of the engine compartments, are the two cylindrical boilers (aft) and three Yarrow boilers (forward), the athwartship fire room being between them. In the forward boiler compartment are the remaining five Yarrow boilers, three aft and and two forward, the athwartship fireroom narrowing in from the forward end of the after row of boilers. Both fire rooms are very commodious, the length of each being about 12 feet.

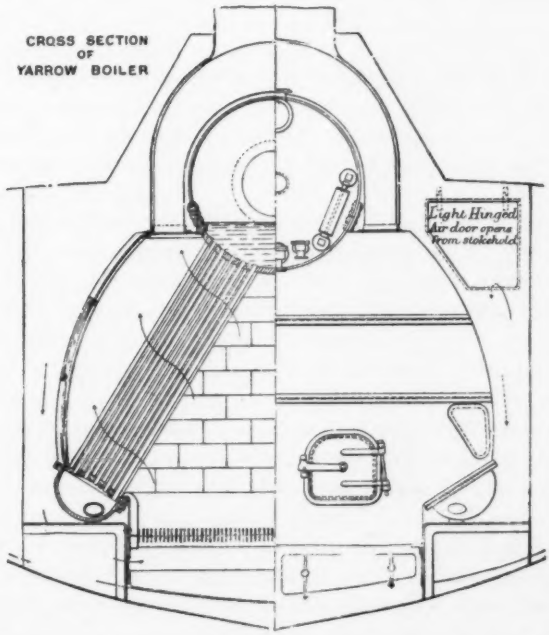
It will thus be noticed that three water tube boilers occupy the same width in the vessel as the two cylindrical boilers, and that the length of the two types of boilers is practically the same. In the matter of height, the water tube boiler has an advantage of 3 feet 9 inches over the shell boiler.

The air pressure with the cylindrical boilers will be, at the maximum, 2 inches, while that of the water tube boilers will be 1 inch. These are the pressures taken for calculation of the powers mentioned above.

As the boilers in the Austrian torpedo boat *Viper*, lately completed by Messrs. Yarrow and described above, were of the same type as those now referred to, but were 10 per cent. smaller, and each of these gave steam for over 1,000 indicated horse power with only $\frac{1}{8}$ inch air pressure in the stoke hold, it will be seen that there is a large margin of power in the case of the water tube boilers.

The three pattern boilers were tested at the works of Messrs. Yarrow & Co. on Friday, February 14. The Dutch Govern-

ment had asked for a test pressure of 290 pounds, which was 90 pounds above the working pressure, but Messrs. Yarrow preferred to test the boilers to 350 pounds. The boilers were carefully trammelled before test and when the pressure was on, and the various members were not found to have altered their positions.



One feature in the installation of the Yarrow boilers, on these as well as other vessels, and shown in the cross section of the boiler, is that the air passes to the fire through openings fitted with light non-return valves which are attached to a diaphragm plate, which is fixed to the front of the boiler. As soon as there is pressure in the stoke holds, the air passes through these valves round the entire casing of the boiler, and then underneath the bars to the furnace, the ash pit doors being kept closed. By this means, the coal bunkers, which generally surround the

boiler, are kept comparatively cool, and what is a much greater advantage, the hinged doors, from their position, are not likely to be distorted, while if they are placed in front below the bars, as previously done, they are very liable to warp out of shape by the heat, and also, by the accumulation of cinders, to prevent the doors from closing properly.

ITALY.

New Cruisers.—Only two vessels are authorized for this year. One is to be an armored cruiser of 10,500 tons displacement, the length to be about 419 feet; beam, 65.5 feet, and draught, 25.25 feet. The I.H.P. is to be 13,000, and a speed of 23 knots is expected.

The other vessel will have a length of 275.5 feet and a beam of 26 feet, the displacement being about 1,100 tons. The I.H.P. is to be 7,000, and a speed of 22 knots is expected.

Sicilia.—The following details of the machinery of this battleship are from "Engineering," London. The principal data of the vessel and her trials were given on page 195 of the February number of the JOURNAL.

The machinery of the *Sicilia* was constructed by Messrs. G. Ansaldo & Co., at Sampierdarena, near Genoa, who, at the suggestion of the Italian Ministry of Marine, entered into an alliance with Messrs. Maudslay, Sons & Field, of London, by which these latter undertook to assist them in the modifications and extensions to be made in the establishment at Sampierdarena, and took the charge and responsibility of the preparation of all new designs for the Italian Navy, as well as the absolute responsibility for the construction of the engines, their delivery, their erection, and the carrying out of the trials.

The machinery is identical with that for the *Umberto*, and made to the drawings of Messrs. Maudslay, from the designs of Mr. C. Sells, who has designed the engines for a number of vessels for the Italian Navy.

It had been proposed to adopt triple-expansion engines, but the Italian authorities decided to repeat the double compounds of the *Umberto*, which at ordinary cruising speeds prove quite as econo-

mical as triple-expansion engines. The arrangement of the main engines is very compact and well balanced. The general plan of the work is similar to that carried out under the specifications of the British Admiralty of that period, except that the tests of material are rather more stringent.

Up to the time of designing the original set of these engines fitted in the *Umberto*, the most powerful engines for a ship of war had been of 12,000 horse power, the English Admiralty having two sets of these actually at work, and several in course of construction. To efficiently utilize the great power of 20,000 horse power, it was decided to have four complete engines, two driving each screw, the forward engines to be disconnected when cruising at ordinary speeds.

Neither the engines of the *Re Umberto*, nor the *Sicilia*, have ever been tried under these conditions, as the reduced power has been obtained in the usual way.

The H.P. cylinder of each forward engine is aft, and of the after engines, forward. The exhaust pipe from the L.P. cylinder to the condenser passes between the cylinders, the condenser for each engine being parallel to the main shaft.

The engines are vertical, inverted, the collective power of the two sets of engines being 15,200 with natural, and 20,000 with forced draft. The cylinders are 47 and 89 inches in diameter, the stroke being 4 feet 3 inches.

The cylinder liners are of cast steel. The high pressure valves are of the piston type, while the low pressure valves are flat and double ported. They are worked by Joy's valve gear, with Sell's modification of horseshoe frames of cast steel, instead of links, as generally fitted. To prevent any change in the setting of the slide valves, all the joints of the working parts of this gear are made non-adjustable, an ample supply of spare bushes being provided; but in actual working, as their surfaces are very ample, the wear on these bushes has been found to be very little, and the valve gear generally has given most satisfactory results.

The starting engine is horizontal and placed between the forward and after sets of the main engines, being connected to the reversing gear of the two sets by means of long rods, so that if the

after engines are to be used alone, it is only necessary to remove one of these rods. Separate stop valves are fitted to the four sets of engines, but throttle valves are fitted in the main steam pipe, for shutting off the steam simultaneously from the forward and after engines should it be necessary.

Each cylinder is carried on four cast-steel columns of the usual Maudslay type, one at each corner. The crossheads are of wrought steel, and have cast-iron shoes at their ends, working between cast-iron guide plates fixed on the columns.

The pistons are of cast steel, and the piston rods are attached to them by means of flanges and bolts. The connecting rods are of steel, the length between their centers, 9 feet. The crankpin bearings are lined with white metal. The crankshafts are of steel, made in four parts, the diameter of the forward shaft being 15½ inches, and that of the after one, 19½ inches. The bed plates are of cast steel. The thrust blocks are fitted with movable collars of hard brass lined with white metal; both the upper and lower parts are arranged for water circulation.

The screw propellers are of the ordinary 4-bladed type, 20 feet in diameter and 20 feet mean pitch. The blades are attached to the bosses by screw bolts, and the pitch is adjustable for two feet in either direction. Coned caps are fitted over the nuts on the ends of the stern shafts.

The main condensers are of brass, and have a cooling surface of 30,000 square feet. They are also arranged for use as jet condensers. The inclined air pumps are of brass, and are worked directly from the connecting rods of the main engines by means of rods.

The centrifugal circulating pumps are driven by separate engines, and are each able to discharge 450 tons of water per hour. A double-cylinder feed pump of the Admiralty type is fitted in each engine room, and an auxiliary feed pump of the same type in each boiler room, and so arranged that any pump can supply any of the boilers. A double-cylinder fire pump and two bilge pumps of the same type are also fitted in each engine room, as well as a double-plunger hand pump.

The main boilers are eighteen in number and arranged in six

compartments, four forward and two aft of the engine rooms, the after boilers being raised sufficiently to permit the screw shafts passing under them. The safety valves are loaded to 100 pounds pressure per square inch, and the boilers were proved to double that amount by hydraulic pressure. Each boiler is 14 feet 3 inches in diameter and 9 feet 7 inches long, and has four plain furnaces, 3 feet 2 inches in diameter, each furnace being in two sections, joined by an Adamson ring. There is one funnel for the six after boilers and two for the twelve forward boilers, these latter being placed side by side athwartship and forward of the single military mast. There are two auxiliary boilers.

The main boilers are single-ended, with inclined front heads. The back heads are flat, except for a distance of 3 feet 4 inches from the bottom, where they are inclined. There are three rows of irregularly-spaced $2\frac{1}{8}$-inch screw braces, 18 in all, running through the steam space in each boiler, the nuts in the uptake being protected by a light metal cover. The tubes are all $2\frac{3}{4}$ inches in outside diameter and 6 feet 9 inches between tube sheets. There are 302 ordinary tubes of brass, .13 inch thick, and 90 stay tubes of iron, .2 inch thick, in each boiler. The shell plates are $\frac{25}{32}$ inch, the inclined front head $\frac{11}{16}$ inch, and tube plates, $\frac{3}{4}$ inch thick.

There are two auxiliary boilers, 7 feet in diameter and 14 feet 6 inches long, placed on the protective deck, as well as two powerful horizontal fire pumps, so that very considerable pumping power would always be available, even should the vessel be full of water and the fires in the main boilers be put out.

The fitting on board of the propelling machinery was commenced as soon as the vessel was launched, July 6, 1891, and was completed by May, 1893, when the official steaming took place in the presence of a Government commission.

The completion of the vessel, however, went on but slowly, and it was not until May 6, 1895, that she was finally ready to leave for Pozzuoli, whence, the guns having been put on board, the vessel returned to Spezia for her trials.

The six hours' natural draft trial on September 19, the results of which were given on page 195 of the last number of the

JOURNAL, was not considered as showing the real capacity of the machinery. Another six hours' trial was made on October 14, with better stokers, taken from the *Sardegna*, then in commission The mean I.H.P. was increased by about 350, and the trial pronounced satisfactory.

The forced draft trials were postponed on account of sudden orders to complete the vessel for active service. She is now ready for these trials.

Like all the large vessels of the Italian navy, she is fitted with Colonel Cuniberti's apparatus for injecting petroleum on the incandescent fuel, and it is expected that in this manner results will be obtained equal, if not superior, to those obtained with forced draft, but without its disadvantages.

Carlo Alberto.—This armored cruiser, a sister ship of the *Vittor Pisani*, described on page 830 of Vol. VII, was launched on March 14, 1896, at Spezia. The machinery was built by Messrs. Ansaldo & Co., Genoa.

JAPAN.

Yashima.—This first-class battleship, built by Messrs. Armstrong, Mitchell & Co., was launched on Friday, February 28, at their Elswick yard. The construction of this vessel was commenced on Dec. 6, 1894. She is a sister vessel of the *Fuji*, mentioned below. The contract price of this vessel was $3,900,000.

The following description is compiled from "Engineering," London:

Length over all, feet	412
on load water line, feet	400
between perpendiculars, feet	372
Beam, extreme, feet	73.5
Depth, feet and inches	43–7⅝
Draught, normal, mean, feet	26.25
Displacement at above draught, tons	12,320
Coal supply, normal, tons	700
full bunkers, tons	1,200
I.H.P., natural draft	10,000
Speed, with above power, knots	16.75
I.H.P., forced draft, 1½ inches of air pressure	13,500
Speed, with above power, knots	18.25

There is an armored belt 226 feet long by 8 feet deep, which at normal draught will extend 3 feet above and 5 feet below the water line. In the middle it is 18 inches thick, 16 inches at the intermediate parts and 14 inches at the ends. The space aft of the citadel is chiefly given up to storerooms. The special framing behind the belt armor consists of deep web frames; the teak backing, which is of approved design according to Navy practice, is 4 inches thick. Special armor bolts are used, there being one to about every square foot of surface. Over the machinery space there is a flat protective deck, 2½ inches thick, extending athwartships from the top edges of the belt, and therefore above water. At the ends, the deck is lower, and also slopes down at the sides in the usual way, so that it is below water level. Above the thick belt there is 4-inch armor to the main deck. There is a barbette of the usual pear shape at each end of the citadel. The front of each one is 14 inches thick down to the main deck. Below this, and down to the protective deck, the barbette armor is 9 inches thick, it being behind the 4-inch side armor. The horseshoe shaped shields to the barbette guns are of 6-inch armor at the front, thinning somewhat to the rear, the end being quite closed, as in the *Magnificent*. From each of the barbettes there are two screens of 4-inch armor between the main and protective decks. These screens are not quite square athwartships, the forward ones tending aft at a small angle, and the after ones forward. At the rear of the barbettes, the armor is 5 inches thick. The conning tower armor is 14 inches thick, and there is a director tower of 3-inch armor. All heavy armor is harveyized, and has been supplied by Messrs. Charles Cammell & Co. The coal storage is arranged so as to give protection against shell fire as far as possible.

There will be two 12-inch, 49-ton guns, in each barbette; they will command an horizon of 30 degrees to the rear of each barbette on both beams. There will be ten 6-inch rapid fire guns, six of these being on the upper deck. The two forward and the two after guns will have a range of fire of 90 degrees before and 60 degrees abaft the beam. The two 6-inch guns amidships will train 60 degrees before and abaft the beam respectively. The

four remaining 6-inch guns will be on the main deck, each one being mounted in a casemate having 6-inch armor on the front and 2-inch armor on the rear part. The 6-inch guns on the main deck are carried on what may be described as half-sponsons; that is to say, at the bottom part, or main deck level, they do do not project beyond the ship's side, but above this, as the vessel's side tumbles home and the casemates are carried vertically upwards, there is a sponson shaped projection. These casemates are protected against raking fire by the 4-inch screens before mentioned. The upper deck guns are placed behind the usual heavy steel shields.

There will be twenty-four rapid firing guns, twenty being 3-pounders, and four, which will be placed in the tops, being 2½-pounders. Of the 3-pounders, eight will be placed on the bridges, four on the bulwarks, and eight on the main deck. There are five 18-inch torpedo tubes, four on the broadside and submerged, and one in the bow. The vessel will carry 15 torpedoes. There will be two military masts, each with two fighting tops, and two smoke pipes.

There will be a large bridge forward over the conning tower and abaft the forward barbette. On this will be placed the chart house. The conning tower is on the end of the barbette, an arrangement which allows of voice tubes, telegraphs, steering rods, &c., being well protected, as they go down the ammunition hoist. There is a somewhat smaller bridge aft, these two athwartship bridges being connected by fore-and-aft bridges.

The boats are to be carried on skids in the usual way, and there is a derrick with steam winch for lifting them placed on the upper deck. A donkey boiler on the main deck supplies steam to the derrick, capstan engines, &c. There will be two 56-foot torpedo vedette boats, a 42-foot launch for countermining, a 30-foot steam pinnace, a 28-foot cutter, a 30-foot and a 27-foot gig, a 27-foot life boat, besides smaller boats and life rafts. A 2½-pounder gun will be placed in each of the larger boats.

The vessel has bilge keels running nearly half the length of the ship and about 2 feet 6 inches deep. The bottom appeared, as the vessel was in construction, to be rather flatter amidships

than some designs for this class of vessel, but the ends are beautifully fine, the endeavor being, apparently, to get stability by a squarer bilge than usual. The flat keelplate is of the ordinary construction, and there is the usual cellular double bottom with longitudinal framing. Within the citadel are deep frames, and beyond the frames are rolled Z-bars split to take the floors. The stem and ram are of cast steel in one piece. The rudder frame and the stern frame are also steel castings. The propeller shaft struts are two steel castings meeting under the keel, where they are scarphed together and bolted through the keel, the upper ends being attached to the ship by palms as usual. The bottom rises towards the after end, and a balanced rudder is used, as originally introduced in torpedo craft and now applied to cruisers.

The *Yashima* is intended to be used as a flagship. The Admiral's cabin is in the extreme after part on the main deck. This room is about 40 feet in length, and looks out on the quarter gallery. Immediately forward is the dining room, which is 15 by 30 feet. The state room and bath room are adjoining. The officers' state rooms are on each side of the ship. The crew's quarters are forward in the usual positions, there being messing room for the whole ship's company of 600 at one time. From the main deck is to be seen the extensive provision made for strengthening the upper deck near the barbettes, to provide against the blast of the 12-inch guns. This consists chiefly of deep girders supported by pillars, &c. The steel bulkheads dividing the officers' rooms are also strengthened for this purpose.

The coal bunkers extend from the belt deck to the main deck through the whole length of the citadel; in the midship bunkers there is over 12 feet of coal, this amount decreasing as the ship narrows. All hatches and openings in the belt deck are protected by coffer dams, 3 feet high, or 6 feet above the normal water line. All hatches, smoke pipe and ventilator openings have either armored doors or armored bars at the level of the protective deck.

On this belt deck, outside of the citadel, there is accommodation for some of the officers aft and for part of the crew forward.

The wardroom, which is aft, is 40 by 25 feet. Forward on this deck is the bow torpedo tube.

On the lower deck and below the base of the barbettes (the latter standing on the protective deck) are athwartship armored bulkheads joining the ends of the port and starboard armor belt. These bulkheads are beyond the ends of the barbettes and are at right angles to the center fore-and-aft line, not sloping as the 4-inch screens above. The forward bulkhead is 14 inches and the after one, 12 inches thick. On this deck, and protected by the belt and the coal when in the bunkers, there is an ammunition passage for serving the 6-inch guns, extending around the machinery space, which at this level occupies the greater part of the citadel. The magazines are below, and the ammunition is brought up by hoists and served from this passage to the gun positions through armored hoists. The arrangement is very convenient, as the ammunition is thus taken direct to the guns by a straight lead, and has to be handled only behind armor. Forward and aft of the machinery space, but within the citadel, on this deck, are two sets of hydraulic engines for working the barbette guns. Forward, beyond the citadel, on this deck, are tanks, stores and chain lockers.

The main part of the lowest or platform deck is occupied by the machinery space, but between the engine rooms and extending their whole length, and in height from the protective deck to the inner bottom, is an important compartment, about 9 feet wide and 40 feet long. This is divided into engineer's workshops, engineer's storerooms and gunner's stores. The workshops being placed here are very convenient for repairs, and by the arrangement a double bulkhead is afforded between the engine rooms. This may prove to be an important feature in a war vessel, and, remembering the *City of Paris* mishap, it may also be of use in a merchant vessel. Outside of the machinery space are the magazines, shell rooms and handling rooms; the submerged torpedo rooms and steering compartment aft, and the other submerged torpedo rooms, capstan engine and boatswain's stores forward. The hold is occupied by magazines, submarine mines, ballast tanks and torpedo workshops. There are 181 water

tight compartments, of which 36 are in the double bottom, 70 in the hold, 18 on the platform deck, 29 on the lower deck, 22 on the belt deck and 6 on the main deck.

The machinery is supplied by Messrs. Humphreys, Tennant & Co., Deptford. There are two triple-expansion engines with cylinders 40, 59 and 88 inches in diameter and 45 inches stroke. There are ten single ended, cylindrical boilers, each with four furnaces. They are placed in four compartments, three boilers in each forward and two in each after compartment.

The *Yashima* is not unlike the new battleships just proposed, but, though of less displacement, has a somewhat greater draught. The main armament is the same, so far as number and caliber of guns are concerned, but it may be that the *Yashima's* guns will be longer than those of the British ships. The *Yashima* still more nearly approaches the *Renown*, being about the same length, 18 inches wider, and practically the same displacement, the draught of the British vessel being somewhat greater. In place of the four 12-inch guns of the *Yashima*, the *Renown* has four 10-inch guns. The number of 6-inch guns is ten in each vessel. The *Yashima* exceeds in size H.M.S. *Barfleur*, which now ranks as a first-class battleship, the latter being about 2,000 tons less displacement than the *Yashima*. The British vessel has, however, four 29-ton guns as her main armament, in place of the four 49-ton guns of the Japanese vessel, and but eight of the 4.7-inch guns in place of the ten 6-inch guns. On the other hand, the *Majestic*, which is nearly 15,000 tons displacement, has, like the *Yashima*, four 12-inch guns, but the guns in the British vessel may not be so long, and will, therefore, be a trifle lighter.

Fuji.—A sister ship of the *Yashima*, was successfully launched on Tuesday, March 31, by the Thames Iron Works. The machinery was built by Messrs. Humphreys, Tennant & Co., Deptford.

The launching weight of the *Fuji* was 7,500 tons, said to be the heaviest vessel ever launched in a private or public yard. Including the cradles, the dead weight on the ways was about 2½ tons per square foot.

The general dimensions of this vessel are given as slightly different from the *Yashima*.

Length between perpendiculars, 374 feet; beam, 73 feet; draught, 26.5 feet; displacement at this draught, 12,450 tons; I.H.P., 14,000, and speed, 18.75 knots.

PORTUGAL.

A fast cruiser and two gunboats are to be built by the Thames Shipbuilding and Iron Works Company.

RUSSIA.

George the Victorious.—This battleship, of the Black Sea Fleet, the principal data of which were given on page 129, Vol. IV, has had her trials. She was launched in 1892.

The armor belt has a maximum thickness of 15.75 inches and the barbettes, 11.81 inches. The protective deck is about 2.75 inches thick.

SWEDEN.

Odin.—This first-class coast defense vessel was launched at Stockholm on March 9, 1896. The length is 278.8 feet; beam, 49.21 feet; draught, 16.5 feet; displacement, 3,346 tons. A speed of 16 knots is expected.

The armament will consist of two 9.8-inch Canet guns in turrets, four 4.7-inch rapid fire guns in casemates, four 6-pounders, four 1-pounders, two machine guns, and one submerged, bow torpedo tube.

The vessel has twin-screw engines, which are designed for about 3,700 I.H.P.

The turret and side armor is 12 inches thick.

MERCHANT STEAMERS.

Atlanta.—This steel passenger and freight steamer, built by the William Cramp and Sons' Ship and Engine Building Co., Philadelphia, for the Southern Railroad Co., to run between Norfolk and Baltimore, was launched on Wednesday, March 18. The following data and description are from the "American Shipbuilder," New York:

Length over all, 240 feet; length between perpendiculars, 232 feet; beam, 42 feet; and depth, 15 feet. The vessel is built of steel up to saloon deck, with scantlings according to highest class in the "Record of American and Foreign Shipping." The passenger accommodations are above the saloon deck, and are very extensive and elaborately fitted up, there being a spacious and well lighted dining saloon forward, with pantry and galley above same conveniently arranged. There are state rooms for 100 passengers—all outside rooms—also spacious lavatories, toilet rooms, &c. All the passenger accommodations are separated from the cargo spaces by iron partitions, making them secure in case of fire and excluding any odors or dust. The machinery enclosures are of iron to top of deck houses. There is one triple-expansion engine with cylinders 24, 38 and 62 inches in diameter and 36 inches stroke. All the main shafting is of steel and the propeller of manganese bronze. The feed and circulating pumps are independent. There are four steel boilers 12 feet in diameter, 12 feet long, the working pressure being 160 pounds per square inch. Each boiler has two corrugated furnaces, the total grate surface being 200 square feet and the heating surface, about 6,000 square feet. There is a Williamson steam steering engine, and a complete electric light outfit, with a search light of 2,000 candle power. The builders have guaranteed a continuous speed of 15 knots on the vessel's route.

India.—The first one of six new single-screw steamers ordered

by the Peninsular and Oriental Co. was built by Messrs. Caird & Co., Greenock, Scotland, and launched on April 15. Four of these steamers are building by the above firm and another, the *China*, by Messrs. Harland & Wolff, Belfast, Ireland. They are to be 500 feet long, with a beam of 54 feet, a depth of 37.5 feet, and a registered tonnage of about 8,000 tons. They will have triple-expansion, four-cylinder engines, which are to develop 11,000 I.H.P. Howden's system of forced draft will be fitted. There will be accommodation for 500 saloon passengers.

Inchmona.—This steel steamer, built by Messrs. Wm. Gray & Co., West Hartlepool, was launched on February 29. The length is 335 feet; beam, 46.5 feet; depth, 26.33 feet; and dead-weight carrying capacity, 5,000 tons on a draught of 20.5 feet. Water ballast tanks, of a capacity of 920 tons, are fitted forward and aft. The machinery consists of the first set of Mr. Thos. Mudd's patent quadruple-expansion, five-crank engines, and has been built by the Central Marine Engine Works. The two L.P. cylinders are each 42 inches in diameter. There are two cylindrical boilers, the working pressure being 255 pounds per square inch.

Mohawk.—This steel, paddle wheel freight steamer, built by the Delaware River Iron and Shipbuilding Co., Chester, Pa., for the Central Vermont Railroad Co.'s service between New London and New York, was launched on March 7, after an unsuccessful attempt made on February 29. A sister vessel, the *Mohegan*, built at the same yard, was launched in April.

The length is 280 feet over all; beam of hull, 43; beam over guards, 60 feet; depth, 19 feet; displacement on a draught of 12 feet, 2,100 tons.

The engines will be triple-expansion, with cylinders 22, 35, and 56 inches in diameter, the stroke being 42 inches. There will be three cylindrical steel boilers, 125 feet in diameter and 12 feet long, the working pressure being 165 pounds per square inch. Howden's forced draft system will be used.

The estimated speed is 15 miles per hour. Both vessels were designed by Mr. Frank E. Kirby, of Detroit, Mich.

L. C. Waldo.—This steel freight steamer, building by Messrs. F. W. Wheeler & Co., West Bay City, Mich., for Messrs. Waldo & Roby, of Detroit, Mich., was launched on Saturday, March 7. The principal dimensions are as follows: Length over all, 400 feet 9 inches; length on keel, 380 feet; beam, moulded, 48 feet; depth moulded, 28 feet.

Her construction embodies the most improved practice and fulfills the highest requirements of any registry in connection with the Lakes. The double water bottom is built on the cellular system and is 5 feet 6 inches deep, with a capacity of 2,000 tons. She is built on the channel system, with frames, 6 inches × 3 inches × 17 pounds, spaced 24 inches apart, and channel web frames, 15 inches × 3½ inches × 33 pounds, spaced every 8 feet. There are eleven hatches, spaced 24 feet between centers, which, with her carrying capacity of 3,800 gross tons on 14.5 feet draught, will make her one of the easiest handled and largest carriers on the Lakes.

In general appearance the *Waldo* differs little from the usual Lake style of steamer; three pole spars, pilot house well forward, and boiler house and cabins aft. In equipment she is the equal of any vessel on the Lakes, being provided with steam windlass and capstan; Williamson Bros. steam steerer; *Vulcan* patent stockless anchors; and a complete electric light plant, including search light.

There is one triple-expansion engine, with cylinders 23, 37½ and 63 inches in diameter, and 44 inches stroke, built by Messrs. F. W. Wheeler & Co., in their own shops. The high and intermediate pressure cylinders are fitted with piston valves and the low pressure, with a double ported, balanced slide valve, all worked by a Stephenson double-bar link motion. There is a powerful steam reversing gear. Crossheads and connecting rods are wrought iron; the former are fitted with large slippers and the latter have the upper ends forked to suit crossheads. All pistons are cast iron, and are fitted with self-setting spring rings. The framework consists of six cast-iron columns, the three rear

NOTE.—Most of the data of S.S. *L. C. Waldo* and *City of Bangor* were kindly supplied by the builders, Messrs. F. W. Wheeler & Co.

columns being Y-shaped, and having large bearing surfaces for the slides. The bed plate is cast in one piece and has five main journals. The crank shaft is 12 inches in diameter. The cranks are placed 120 degrees apart in the order of high, low and intermediate. The thrust shaft is 12 inches in diameter, and has four large collars. The thrust bearing is of the horse-shoe type and easily adjusted. The propeller shaft is 12 inches in diameter and 12½ inches in the stern bearing. The latter consists of a sleeve 5 feet long, made in halves and lined with lignum vitæ. The propeller is four bladed, of cast iron, with detachable blades, and is 13.5 feet in diameter, and has a pitch of 17.5 feet.

There are two cylindrical, return-tube boilers, 15 feet in diameter and 12 feet long, built by Wickes Bros., of Saginaw. The working pressure is 170 pounds per square inch. Each boiler has three 44-inch furnaces, four hundred and seventy-seven 2½-inch tubes, a grate surface of 60 square feet, and a heating surface of 3,115 square feet. The boilers are fitted with Ellis & Eaves' system of induced draft, which is here used for the first time on the Lakes. The two Sturtevant fans for inducing the draft are 7 feet in diameter, each driven by a 6×5-inch double, enclosed steam engine. These fans are placed at the after end of the boilers and are connected to them by two air heating boxes on top of the boilers, each box containing one hundred and forty-eight 3-inch tubes, 16 feet 7½ inches long. The gases pass from the boilers through the air heating boxes to the fans, from which they are discharged through the smoke pipe.

The total cost of the vessel is about $225,000.

City of Bangor.—This steamer, built by Messrs. F. W. Wheeler & Co. for Messrs. Eddy Brothers & Co., of Bay City, Mich., was launched on Wednesday, March 18. The following are the principal dimensions: Length over all, 384 feet 6 inches; length on keel, 366 feet; beam, moulded, 44 feet 6 inches; depth, moulded, 26 feet 7 inches.

Her hull is similar to that of the *Waldo*, with the exception of the water bottom, which is 54 inches deep. She has ten hatches, spaced 24 feet between centers, and a carrying capacity of 3,400

gross tons on 14 feet 6 inches draught. The equipment and rig are the same as those of the *Waldo*.

The triple-expansion engine is of the same type, with cylinders 22, 35½ and 59 inches in diameter and 44 inches stroke. The propeller is 13.25 feet in diameter and has a pitch of 16.5 feet. All pumps are independent. There are two cylindrical return-tube boilers, each 15 feet 6 inches in diameter and 12 feet long, the working pressure being 170 pounds per square inch. Each boiler has four furnaces, 41 inches in diameter, 362 3¼-inch tubes, 78 square feet of grate surface and 3,135 square feet of heating surface.

Elisabeth Rickmers.—This steel steamer, built by Messrs. Wigham, Richardson & Co., Newcastle, for the Rickmers Co., Bremen, was launched at the end of March. The principal dimensions are: Length, 427 feet; beam, 50.5 feet; depth, 30 feet; and a carrying capacity of about 7,200 tons dead weight.

The engines are of the quadruple-expansion type, balanced according to the Yarrow, Schlick and Tweedy system. The working pressure will be 215 pounds per square inch.

Besides this steamer, the Messrs. Rickmers have ordered two others of the same size, but with machinery of different types, so as to have an opportunity of making a practical test of the various systems. The *Marie Rickmers* will have a triple-expansion engine, the boiler pressure to be 185 pounds per square inch; the *Ellen Rickmers* will have boilers with the same working pressure, but forced draft will be used.

Frank Rockfeller.—This steamer was successfully launched at the American Steel Barge Co.'s yard, West Superior, Wisconsin, on Saturday, April 25.

The following description is from the "Marine Record," Cleveland:

The *Rockfeller* is 384 feet long, and has 45 feet beam and 26 feet depth.

Her capacity will be 4,000 tons, or about 135,000 bushels of wheat on 14½ feet, or over 220,000 bushels of wheat on 20 feet draught.

In the construction of the *Rockfeller*, the bulb-angle system of

framing is used. The water bottom is 48 inches deep, and is constructed on the McIntyre principle. The compartments will hold 1,600 tons of water ballast.

The hull departs somewhat in appearance from the other whaleback steamers. The deck has less crown and the topsides are straighter. The pilot house is separate from the main cabins, the intervening space of 34 feet being occupied by fueling hatches. The old plan of placing engines and stacks in separate tunnels has been abandoned, and one large turret protects the whole of the space. This greatly improves the ventilation of both engine and fire rooms. The boilers are placed higher than has heretofore been the practice, affording additional cargo space.

There are eleven center line cargo hatches, each 12 × 8 feet, and ten side hatches, each 6 × 4 feet, the latter located upon the port side of the ship, this arrangement allowing twenty-one ore spouts to be lowered into the vessel at one time, thereby reducing the time required for loading.

There is one triple-expansion engine, with cylinders 23, 38, and 63 inches in diameter by 40 inches stroke. There are three Scotch boilers, 12 × 13 feet, each with three 38-inch furnaces, and allowed 175 pounds working pressure. The engines and boilers were built by the Cleveland Ship Building Co. The steam windlass and deck capstans were made by the Bath Iron Works, of Bath, Maine. The propeller is 13½ feet in diameter, with a pitch of 16 feet. The expected speed is 14 miles per hour.

Coralia.—This twin-screw steamer, built by the Globe Iron Works, Cleveland, Ohio, for the Mutual Transportation Company, was launched on Saturday, February 22. The length is 432 feet over all, and 412 feet between perpendiculars; beam, 48 feet; depth, 28 feet. When drawing 19 feet the net capacity will be 6,680 tons, and at 14.5 feet, 4,180 tons.

The frames are of Z-bars, 6½ × 3⅝ inches, spaced 2 feet apart, with web frames at intervals. The stanchions are of I section. The deck beams are bulb T's, spaced 4 feet apart. The cellular double bottom is 60 inches high. The best open hearth steel was used in the construction of the hull.

The engine is of the inverted, triple-expansion type with cylinders 23, 39 and 63 inches in diameter, the stroke being 42 inches. There are four Scotch boilers, 11.5 feet in diameter and 10 feet long, placed in pairs athwartships.

The total heating surface is 4,336 square feet, and the grate surface, 160 square feet. The working pressure will be 160 pounds per square inch.

George N. Orr.—This steel freight steamer, built by the Chicago Shipbuilding Co., South Chicago, Ills., was successfully launched on Saturday, April 14. The length over all is 340 feet; on keel, 326 feet; beam, 42 feet; and depth, 26 feet. There is one triple-expansion engine, with cylinders 20, 33 and 54 inches in diameter, the stroke being 42 inches. There are two boilers 12 feet in diameter and 12 feet long.

Reina de los Angeles.—This passenger and freight steamer, built for Messrs. Menendez & Co., of Cienfuegos, Cuba, was launched by the Neafie & Levy Ship and Engine Building Company of Philadelphia, on Saturday, March 14. She is intended to carry passengers and freight between ports on the south coast of Cuba. The new vessel is finely fitted, and has accommodations for 100 passengers. Her length is 244 feet; beam, 35 feet; depth of hold, 22 feet; gross tonnage, 1,300 tons. She has vertical, twin-screw, triple-expansion engines of 1,200 horse power. The surface condensers are supplied with water by centrifugal pumps of a capacity of 120,000 gallons per hour. Three large independent pumps are arranged for fire, feed and sanitary purposes. A complete modern electric light plant will be placed in the lower engine room, supplying search and incandescent lights. There are four steel boilers. She is the sixth vessel built by the Neafie & Levy Company for Menendez & Co.

Ekaterinoslav.—This auxiliary steel cruiser, built for the Russian Volunteer Fleet by Messrs. Hawthorne, Leslie & Co., Hebburn-on-Tyne, was launched on January 30. The principal dimensions are: Length, 450 feet; beam, 50 feet; depth, 32 feet.

The engines, building by the St. Peter's Works, are of the twin-screw triple-expansion type, with cylinders 21, 34 and 55

inches in diameter, the stroke being 42 inches. The designed speed is 20 knots.

Minneburg.—This steel screw steamer, built for the Hansa Steamship Co. of Bremen, was launched on February 18, 1896, from the works of Sir Raylton Dixon & Co., Middlesbrough, England. The length is 323 feet; beam, 42.5 feet; molded depth, 25 feet; and deadweight capacity, 3,600 tons. The engines are quadruple-expansion, built under German requirements by Messrs. Wigham, Richardson & Co., Newcastle-on-Tyne. The cylinders are 19½, 28, 42 and 61 inches in diameter, the stroke being 42 inches.

There are two cylindrical boilers, the working pressure being 215 pounds per square inch.

On April 10 a successful trial was made.

Algoa.—This screw steamer, built and engined by Messrs. Wm. Doxford and Sons, Pallion, had her trial trip on March 24. The vessel, at this date, is the largest cargo vessel yet built in Great Britain, her deadweight capacity being 11,375 tons. The dimensions are: Length, 465 feet; beam, 58 feet; depth, 35 feet; and load draught, 20 feet. She has triple-expansion engines with cylinders 29, 50 and 80 inches in diameter, the stroke being 51 inches. There are two single-ended boilers fitted with Ellis and Eaves' induced draft and Serve tubes. The estimated speed of the vessel was 10½ knots when loaded, but on the full power trial, a speed of about 11½ knots was attained.

City of Buffalo.—This side-wheel steamer of the Cleveland and Buffalo line was built by the Detroit Dry Dock Co. The following description is condensed from the "Marine Review," Cleveland:

Her cost complete will be about $350,000, and a speed of twenty miles an hour in regular service is expected. She was designed by Mr. Frank E. Kirby, of the Detroit Dry Dock Co., who designed and built the *City of Cleveland*, *City of Detroit* and other big side-wheel steamers of the Detroit & Cleveland Steam Navigation Co. Her principal dimensions are: Length on water line, 298 feet; length over all, 308 feet; breadth over hull, 41

feet; breadth over all, 75 feet; depth, midship, 17 feet 4 inches; draught, light, 9 feet 6 inches; draught, loaded, 11 feet 6 inches.

The steel hull is divided into eleven compartments, communication between which is by automatic water tight doors, which can be operated from the deck. Coal bunkers are athwart ship, forward and aft of the boilers, and have capacity of about 350 tons of coal. The engines were built by the W. & A. Fletcher Co., Hoboken, N. J., and are of the compound beam type, with a high pressure cylinder, 52 inches in diameter by 8 feet stroke, and a low pressure cylinder, 80 inches in diameter by 12 feet stroke. They are fitted with Sickle's valve gear. There is a pressure feed water heater of sufficient capacity to condense steam from all of the engines, some sixteen in number. No other lake steamer of her type has a cylinder exceeding 68 inches in diameter. There are six, two-furnace, Scotch boilers, each 12 feet 6 inches in diameter and 12 feet long. They are allowed 125 pounds per square inch working pressure. The weight of the six boilers is 250 tons without water and about 500 tons when filled with water. The Howden system of hot draft will be fitted. The elliptical smoke stack is 7 by 9 feet and 65 feet high. The wheels are of the Clyde feathering type, 30 feet 6 inches in diameter, and when set up complete weigh 58 tons each. The main shafts are 29 feet long and 24 inches in diameter, and weigh 18½ tons each. There is an electric light plant capable of supplying 1,500 to 2,000 lamps, in addition to a search light.

The entire main deck forward of the passenger gangways, which are some distance aft of the wheel houses, will be given up to freight. The social hall, entered from the passenger gangways, is finished in light mahogany, highly carved. Adjoining this are offices and the baggage room, and aft of it is a day cabin. The main dining room is below the main deck; it is finished in oak and will seat about 150 people. Kitchen and pantry are forward of the dining room. The grand saloon, from which entrance is gained to all state rooms, is 250 feet long, and is surrounded by a gallery that leads to the second tier of state rooms; the lower portion is finished in solid dark mahogany, with pressed leather panelings of artistic design, while parts surrounding and

above the gallery are of delicate tints with gold tracings. Accommodations for passengers include 160 state rooms, besides six parlors with bath and other accommodations, and 150 single berths, making in all berths for 640 people.

John Englis.—The contract for this single-screw steel passenger and freight steamer has been given to the Delaware River Iron Shipbuilding and Engine Company, Chester, Pa., by the Maine Steamship Company. The vessel is to run between New York and Portland, Maine. The length will be 315 feet over all; beam, 46 feet; tonnage, 3,500. She will have a large freight capacity, and have about 110 staterooms for passengers.

The engine will be triple-expansion, with cylinders 28, 44 and 73 inches in diameter. There will be four Scotch boilers.

The speed expected is 18 knots, and the estimated cost about $300,000.

Truma.—This steel screw steamer, built by Messrs. Short Brothers, Sunderland, has the following dimensions: Length, 255 feet; breadth, 36 feet 9 inches; and depth molded, 20 feet 4 inches, with a deadweight carrying capacity of about 2,550 tons. The triple-expansion engine has cylinders 19, 31 and 51 inches in diameter, with a stroke of 36 inches. The working pressure of the boilers will be 180 pounds. The engines and boilers were built by Messrs. Allan & Co., Sunderland. This vessel has been built in the remarkably short period of forty-nine working days, including Shrove Tuesday and March 17, on both of which days the yard was idle, also counting Saturday a full day, and not allowing for lost time through bad weather, the first keel plate being laid on February 1. From commencing to plate the inner cellular bottom to the completion of testing by Det Norske Veritas and Lloyd's surveyors there were only fifteen days.—(From "Engineering," London.)

YACHTS.

Josephine.—This steel yacht, described on page 211 of the last number of the JOURNAL, was successfully launched by the Crescent Shipbuilding Company, Elizabeth, N. J., Wednesday, March 4, 1896. The following data of the machinery are taken from the "American Machinist," New York:

The triple-expansion engine was designed by John Haug, of Philadelphia, and built by John W. Sullivan, of New York.

The cylinders are 18, 27 and 42 inches in diameter, and have a stroke of 28 inches. At the front they are supported by three wrought-iron columns, $4\frac{1}{2}$ inches in diameter, and at the back, by cast columns bolted to the top of the condenser, which is embodied in the framing. The cooling surface is 1,600 square feet. A single-acting air pump, 21 inches in diameter, is bolted to the condenser, and worked by a lever from the L.P. crosshead. The feed and bilge pumps, on either side of the air pump, are operated by the same lever, while the circulating pump is an independent one.

A piston valve is used for the high pressure cylinder, and double-ported slide valves for the others. The steam ports are 3×12, 3×20 and 3×38 inches. The valves are all operated by link motion, the links being of the bar type.

The steam reversing gear is placed between the I.P. and L.P. frames, the guide for the piston rod being bolted to the front I.P. column. The reversing cylinder is 8 inches in diameter. The diameter of piston rods is $3\frac{1}{8}$ inches and of the connecting rods, $3\frac{5}{8}$ inches at the crosshead, and $4\frac{1}{8}$ inches at the crank pin end. The crosshead pins are $4\frac{5}{8}$ inches and the crank pins $8\frac{3}{8}$ inches in diameter by 9 inches long. The main journals are $8\frac{5}{8}$ inches in diameter and 12 inches long. The crank webs are $6\frac{1}{4}$ inches thick and $16\frac{1}{2}$ inches wide. Hand turning gear is provided.

The diameter of the propeller is 9 feet 10 inches and the pitch, 14 feet. The engine is to develop from 1,000 to 1,200 horse power upon a coal consumption of 1,600 pounds per hour.

Giralda.—This steam yacht is building by Messrs. James M. Bayles & Son, at Port Jefferson, L. I., for E. S. Renwick, of Milburn, N. J. The drawings and measurements were furnished by the owner and designer. The hull is of parabolic shape, all the lines being mathematical parabolas, proportioned upon a system devised by the designer.

The length will be 104 feet on the water line and 127 feet over all, the beam 20 feet, and the depth of hold, 11 feet.

She will be schooner rigged, and is expected to steam 12 knots. The net registered tonnage is 145 tons.

Her frame is of live oak, white oak and yellow locust, a part of which was to have been used in a vessel built in the Brooklyn Navy Yard many years ago. The planking is of yellow pine, 2½ inches in thickness. The deck beams are more than an inch larger than it is customary to use in a yacht of the same size.

The hull is divided into four water tight compartments. The deck house will be 74 feet in length, and continuous from the pilot house forward to the saloon aft. Just abaft of the pilot house will be the smoking room, 10 feet square, with toilet and bath rooms connecting. The dining room, 17 feet by 10½ feet, the sailing master's quarters and the butler's pantry will occupy a place aft of the machinery, on deck. Below deck will be two saloons, one forward and the other aft of the machinery. The after saloon will be finished in white and the forward one in red mahogany. Winding stairs, forward and aft, will connect with the deck.

The engines will be of the Wells balanced compound type, two independent engines acting upon cranks placed 90 degrees apart. Each engine employs two double-acting cylinders, the low pressure cylinder, 22 inches in diameter, standing immediately above the high pressure cylinder, 11 inches in diameter; the two cylinders, in fact, being comprised in a single casting. The piston of the high pressure cylinder connects in the usual way to a crank upon the main shaft. The low pressure piston is connected, by

means of two piston rods and two connecting rods, with two cranks exactly opposite to and at each side of the first crank.

The engines will be fitted with piston valves throughout, and have independent admission and cut-off valves. With an initial pressure of 100 pounds, the engines will develop 450 horse-power, and may be instantly reversed when running at full speed.

The crank shaft will be 6 inches and the propeller shaft 5 inches in diameter. The four thrust collars will be 9 inches in diameter. There will be one Lighthall surface condenser, having 600 square feet of cooling surface. The independent combined air and circulating pump will have a steam cylinder 9 inches in diameter by 12 inches stroke, the air pump cylinder being 10 inches and the circulating pump cylinder, 12 inches in diameter.

There will be two independent, vertical boiler feed pumps, and one vertical fire pump, the latter having a steam cylinder 5 inches and a water cylinder 3 inches in diameter, the stroke being 6 inches. These pumps will all be furnished by Mr. M. T. Davidson of New York.

The propeller will be of the Delamater balanced type, 6 feet in diameter, and have a pitch of 8 feet.

There will be two Almy water tube boilers having a combined grate surface of 40 square feet. There will be one smoke pipe with an internal diameter of 35 inches, the outer casing being 41 inches in diameter.

The total cost of the yacht will be about $43,000.

Kanawha.—This composite yacht is building by Messrs. C. L. Seabury & Co., Nyack, N. Y., for Mr. J. P. Duncan, of New York. The length over all is to be 140 feet; on load water line, 114 feet; beam, 17 feet; depth, 9 feet 8 inches; draught, 7 feet.

This yacht has slightly larger dimensions than the *Hiawatha*, described on page 214 of the February number, but the internal arrangements are almost the same. The speed is estimated at 16 miles per hour for three hours. The boiler will be of the Seabury water tube type.

Beatrice.—This yacht is building by Messrs. J. and G. Thompson, Glasgow, for Messrs. O. and R. Goelet, of Newport, R. I. The design is by Mr. George L. Watson. She will be about 250 feet long on the water line and have a tonnage of about 1,720.

There will be eight water-tube boilers, building by Messrs. C. L. Seabury & Co., Nyack-on-Hudson. The working pressure is to be 250 pounds per square inch.

Enquirer.—This steel yacht is building by the Union Dry Dock Company for Mr. W. J. Connors, of Buffalo, N. Y. The dimensions are: Length on load water line, 123 feet 1 inch; over all, 143 feet; beam, 17 feet 6 inches; depth, 10 feet; draught forward, 5 feet, and aft, 6 feet. The engine, built by the Riverside Iron Works, Detroit, is of the triple-expansion type, with cylinders 10½, 17 and 27 inches in diameter, the stroke being 16 inches, and has been delivered at the Union Company's yard. The yacht is to be finished in bird's-eye maple and quartered oak.

———.—This twin-screw yacht is building by Mr. John N. Robins, South Brooklyn, N. Y., for Mr. M. C. D. Borden. The length over all will be 250 feet 6 inches; length on load water line, 212 feet; beam, 28 feet; and depth, 16 feet 8 inches. The engines are building by the North River Iron Works, Messrs. W. & A. Fletcher & Co., Hoboken, N. J. The boilers will be of the Babcock and Wilcox type.

Speedy.—This twin-screw steel yacht, built by Messrs. Ramage & Ferguson, Leith, Scotland, for Baron Barreto of Suffolk, was successfully launched on April 15. The following data are from "The Marine Engineer," London.

The length between perpendiculars is 115 feet; beam 20.5 feet; depth, 12 feet; tonnage, yacht measurement, about 250.

The triple-expansion engines have cylinders 10, 16 and 26 inches in diameter, the stroke being 18 inches. The propellers are of bronze. The starting and reversing levers for both engines are placed together at the forward end of engines, steam reversing gear being used. All pumps are independent. The feed pumps are fitted with automatic control and connected to a feed heater. The dynamo is driven by a two-crank, single-acting compound engine. There is an ash conveyor, patented by the owner. A steam warping windlass is fitted forward and a steam capstan aft.

OBITUARY.

ALBERT S. GREENE.

Chief Engineer A. S. Greene was born in Adams, Jefferson County, N. Y., August 3, 1838. He was a graduate of the Rensselear Polytechnic Institute, Troy, N. Y., receiving the degree of Civil Engineer. He entered the Navy as a Third Assistant Engineer, February 17, 1860; was promoted to Second Assistant, October 29, 1862; to First Assistant, March, 1, 1864, and on March 5, 1871, was commissioned a Chief Engineer.

His tour of sea duty comprised about twelve years of cruising on many vessels, chiefly in the Pacific. He was Chief Engineer of the ill-fated *Vandalia* during the hurricane at Apia, Samoa, March 16, 1889.

His last cruise was on the North Atlantic Station as Chief Engineer of the *Charleston*, then fitting out for the Pacific Station. He was detached from the *Charleston* and placed on the Retired List on August 9, 1893, having the relative rank of Commander.

During the war, he was attached to the office of the Engineer-in-Chief of the Navy in the Navy Depart ment. Mr. Greene, besides his other excellent qualifications, was a very good mathematician. He was on special duty at the water works, Hot Springs, Ark., superintending the installation of the plant for the Army and Navy Hospital at that place. He was twice a member of the Board of Examining Engineers at Philadelphia.

Mr. Greene died at the "Cairo," in Washington, D. C., on Sunday, March 8, 1896.

CHARLES H. BAKER.

Chief Engineer Chas. H. Baker was born in Salem, Mass., January 16, 1831. He entered the Navy as a Third Assistant En-

gineer, August 2, 1855; was promoted to Second Assistant, July 21, 1858; to First Assistant, August 3, 1859; and commissioned a Chief Engineer, October 29, 1861. He attained the relative rank of Captain on February 28, 1889.

His six years of service up to the outbreak of the war was all performed at sea in the East Indian and African squadrons and on the Paraguay expedition. During part of the war he was on the *Wachusetts*, on the Atlantic Blockading Squadron. While assisting in the medical relief of the sick prisoners at City Point, Virginia, in May, 1862, he was captured and held as a prisoner of war for three months. From 1878 to 1881, he was Fleet Engineer on the Asiatic Station. His last cruise was on the *Lancaster*.

During Mr. Baker's tours of shore duty, he was a member of several special boards and of the Experimental Board, was head of Department of Steam Engineering at the Naval Academy and at Navy Yards. His last duty before retirement, which occurred on January 16, 1893, was at the Norfolk Navy Yard. Mr. Baker was always held in high esteem by his professional brothers.

Mr. Baker died at his residence in Washington, D. C., on Wednesday, May 6, 1896.

"PRIZE PAPERS" RESOLUTION.

The following resolution was adopted at the annual meeting, January 11, 1896, and ordered to be printed:

Resolved, That it is the sense of this meeting that the Council of the Society of American Naval Engineers should offer annually the sums of $75 and $25, and appropriate medals for the two best papers on any subjects suitable for the JOURNAL, and written by a member or associate member of this Society, subject to the following rules:

1. Papers must be original and submitted to the Secretary and Treasurer before the first of November of each year.

2. The Council of the Society shall judge the value of the papers submitted and award the prizes to the two best, and "honorable mention" to such other papers as deserve this.

3. Papers receiving the award of "honorable mention" shall be considered the property of the Society for publication in the JOURNAL.

4. All papers submitted shall bear a motto of the author, which motto shall be identified by a separate, sealed communication to the Secretary and Treasurer, giving the author's name and motto. These notes of identification shall be kept by the Secretary and Treasurer, and opened only after the Council has given its judgment on the papers. Then the prizes and "honorable mention" shall be awarded by name and the papers published in the JOURNAL.

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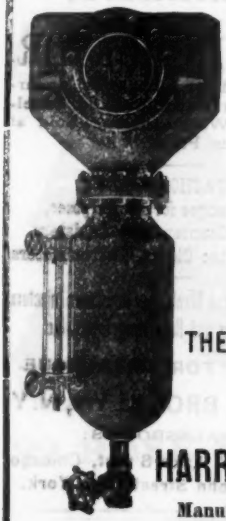

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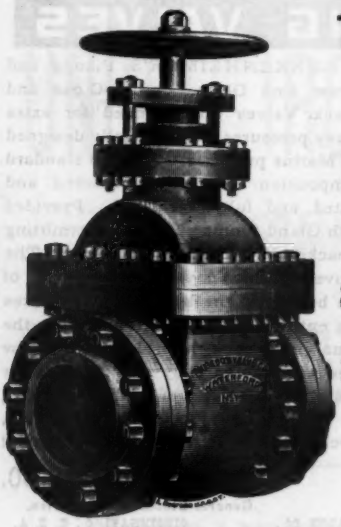

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